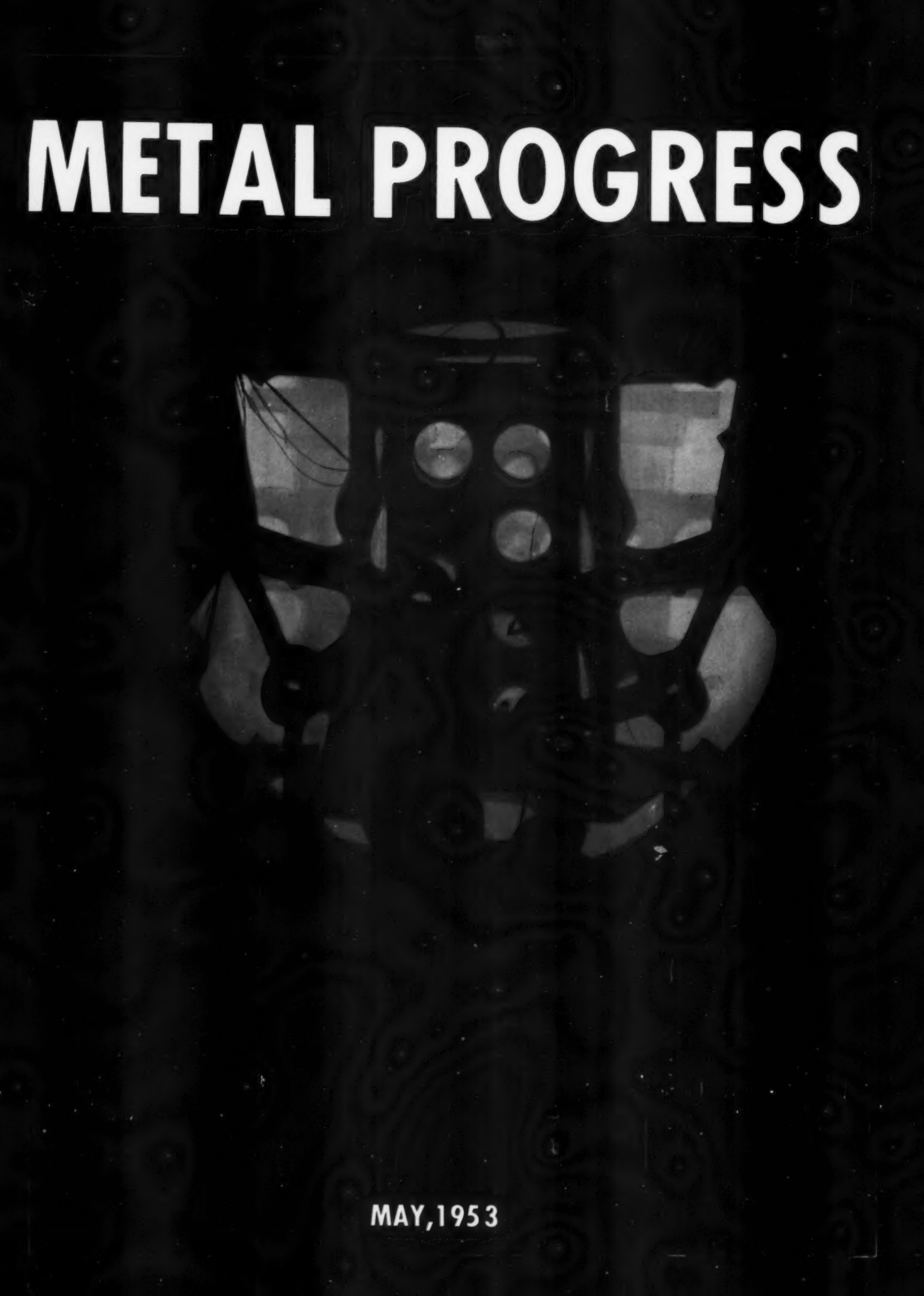
# METAL PROGRESS



MAY, 1953

# 'Surface'

HEATING ALUMINUM cylinder head forgings at Tube Turns, Inc., Louisville, Ky. Surface Combustion convection heated slat conveyor furnace operates at 900 F, producing 4600 lbs/hr net.

## Gas-Fired furnaces for heat treating aluminum

Why use 'Surface' furnaces?

Surface Combustion developed the forced convection type of furnace, which provides maximum temperature uniformity for heat treating aluminum. Also, convection overcomes the reflective properties of aluminum, heating the charge faster and more uniformly than other types of heating. Gas-fired salt bath furnaces for the heat treatment of aluminum and aluminum alloys are also available for special applications.

If you have unusual production requirements, odd-shaped parts, particular shop practices, or space limitations, there's a 'Surface' heat treat furnace to meet your requirements.

Write today.

**SURFACE COMBUSTION** *Corporation*

TOLEDO 1, OHIO

'Surface' INDUSTRIAL FURNACES AND BURNERS

Kathabar HUMIDITY CONDITIONING SYSTEMS

Janitrol AUTOMATIC HEATING EQUIPMENT

## Thousands of Parts Are Heat Treated Daily in 'Surface' Hardening Furnaces

**Successful heat treatment means control of costs, economy in operation, conservation of labor and materials**

★ During the past 10 years people making adding machines, milling machines, tanks, trucks, dies, gears, typewriter parts and many other items have steadily increased their reliance on 'Surface' Standard Rated Hardening furnaces.

Selection of a furnace for hardening operations depends on production rate required, contour and dimensions of the part, temperature required, and desired final surface condition.

*Cutter wheel liquid heated at 1550 F for 20 mins. in 'Surface' Standard Rated Pot Furnace.*

▲*Electric Refrigerator shaft steel hardened in 'Surface' Standard Rated Small Oven Furnace*

To meet these needs, 3 general types of hardening furnaces are available, each in many models and sizes: *Oven Type:* direct-fired; standard hearth areas are 1.5 to 45 sq. ft. Larger sizes are available, if required. For hardening where volume production and flexibility to handle large pieces are important. Send for Literature Group HO.

*Pot Type:* used where charge must be protected from air or decrementally heated. These furnaces are used for heating salt, oil or lead for interrupted quench baths. 24 standard sizes. Circular or rectangular. Send for Literature Group HP.

*Prepared Atmosphere Type:* for complete surface protection and where dimensional stability is required. Muffle type, externally fired. Send for Literature Group HA.

(ADVERTISEMENT)

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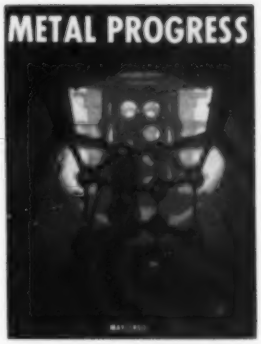


The cover looks down into a nuclear chain reactor in operation. It is a self-photograph, 25-min. exposure. The eery blue glow is generated by neutrons speeding through the water which fills the tank. (Courtesy Oak Ridge National Laboratory and Union Carbide & Carbon Corp.)


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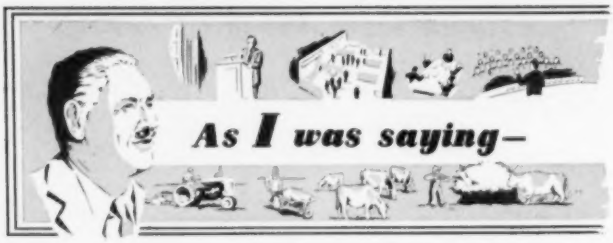
• *See Bill's Column on the other side* ➡




ONE CANNOT HELP but have a feeling of elation and satisfaction when an activity is over and there are heard such words of commendation, praise and congratulations as greeted the close of the Western Metal Congress and Exposition at Los Angeles, March 23 through 27.

The technical sessions were knock-outs—not only the ones presented by the A.S.M., which played to packed houses, but also the meetings held by the A.W.S., S.A.E., A.S.T.E., A.I.M.E., A.F.S., and S.N.T.

Here are a few highlights of the Western Metal Congress: More than 100 papers were presented . . . the new Statler has a fine meeting room floor . . . lots of registration space . . . many palms . . . big patio . . . comfortable lounge chairs . . . L. A. newspapers gave the technical sessions reams and reams of publicity . . . press room was a busy place . . . zirconium, titanium, atomic energy, research, had reporters as eager beavers . . . meetings morning, noon and night . . . none on Friday . . . speakers' breakfast well attended . . . ladies had a busy four-day program . . . Franklin Stamm, chairman of L. A. chapter, had committees well organized . . . all did splendid work . . . over 600 attended the dinner-dance entertainment feature at the Biltmore Bowl on Thursday evening . . . no speakers . . . no introductions . . . so a good time was had by all.

Now the Exposition: Largest ever held in West . . . 325 exhibitors . . . using all space in Pan-Pacific Building plus 40,000 sq.ft. additional under canvas . . . five days of splendid sunshiny weather (many thanks) . . . tent walls were battened down, banked with sand (just in case), while ten giant heaters and 550 gal. of coal oil stood by to take off the chill if such an "unusual" condition should develop (which it did not) . . . electricians worked day and night to hook up equipment . . . over 3000 kva. required . . . an additional substation erected, doubling capacity of the regular station.

Over a million pounds of exhibit material moved in the first two days . . . Show all set and ready for Monday noon opening . . . the Royal Red Carpet first introduced at Philadelphia was laid Monday morning and made a big hit . . . walls draped and decorated with photo-murals depicting the development of aviation since the Wright brothers' day . . . outstanding exhibits . . . many new products . . . attractive displays . . . spaces well manned . . . over 2000 exhibitors' credentials issued . . . 90% of equipment in operation.

And the visitors came . . . from opening gun to final bell the booths and aisles were filled . . . and did they buy! . . . after the first day the "SOLD" sign was on practically every piece of operating equipment . . . on Tuesday received first application for space at the next W.M.E. (1955) followed by many more . . . all want more space to show more equipment . . . you could not find a dissatisfied exhibitor . . . "Best ever" was the expression most used and heard . . . it was a buying crowd . . . clocked attendance 53,453 . . . individual registrants 33,648 . . . all were badged . . . Pan-Pacific management said, "Best show ever in the building" . . . gladly signed lease for next Western Metal Exposition to be held in Los Angeles, March 21 through 25, 1955, and gave A.S.M. options for the building for years 1957, '59, and '61.

The Western Metal Congress and Exposition are fixed features for a two-year cycle in the West.

So here's thanks to members, speakers, exhibitors and staff for a job well done. They are entitled to receive praise and thanks for their fine contributions.

Cordially,

Bill

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS

# RETORT SERVICE LIFE INCREASED 30%

Aetna Ball and Roller Bearing Company produces a wide range of ball thrust bearings for all industry.

## ...when cast in THERMALLOY*

When you want longer service life from your heat treating parts . . . Thermalloy can be the answer. That profitable point was proved at the Aetna Ball and Roller Bearing Company in Chicago, Ill. This company found that *retort service life increased 30%* when cast in Thermalloy.

Shown above are workmen at the Aetna plant removing a batch of ball thrust bearing races from a Thermalloy retort. At this point, the temperature is normally 1750°F., with the heat treating cycle lasting about 5 hours. In operation 24 hours a day, service life of these Thermalloy retorts averages around 10,000 hours with some going full blast to nearly 15,000 hours.

Designed by Electro-Alloys engineers, the shape of this octagonal Thermalloy retort provides Aetna with a sounder casting that gives more uniform tumbling action with less marring of parts.

For retorts, furnace parts, trays, racks, pots, muffles—Thermalloy gives you more operating hours per dollar. Our engineers will help you select the right grade of Thermalloy, engineer the casting and foundry practices necessary to produce a high heat-resistant casting for lowest cost service life. Call in an Electro-Alloys engineer for full information or write Electro-Alloys Division, 4002 Taylor Street, Elyria, Ohio.

*Reg. U. S. Pat. Off.

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION
ELYRIA, OHIO




Metal Progress is published and copyrighted, 1953, by American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscriptions $7.50 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the act of March 3, 1879.

# Application engineering . . . *essential to control*

No matter what the product, every plant uses methods, materials and equipment that present problems peculiar to its own production. Specifications . . . size of plant . . . rate of output . . . all impose further unique restrictions.

What, then, about process control instrumentation? To do its job right, it has to be designed with all those factors . . . and many others . . . in mind. And here is where Honeywell Application Engineering steps in.

First comes a thorough investigation of control requirements. A Honeywell engineering representative, well versed in instrumentation techniques sits down with process engineers, production men, and instrument technicians . . . discusses details of the specific process. Then he puts the problem up to Honeywell's staff of application engineers.

**Specialists for Each Industry**

In this group are men who are expert in each specific industry. One group, for example, specializes in instrumentation for the metalworking industry . . . another for chemical . . . another for petroleum . . . until the whole gamut of modern manufacturing is represented. Each man has been trained, by education and first-hand experience, in the techniques of processing and process control in the area of his interest. Each is a living part of the industry he serves. And he knows why and where every process "is different."

**Covers All Aspects of Control**

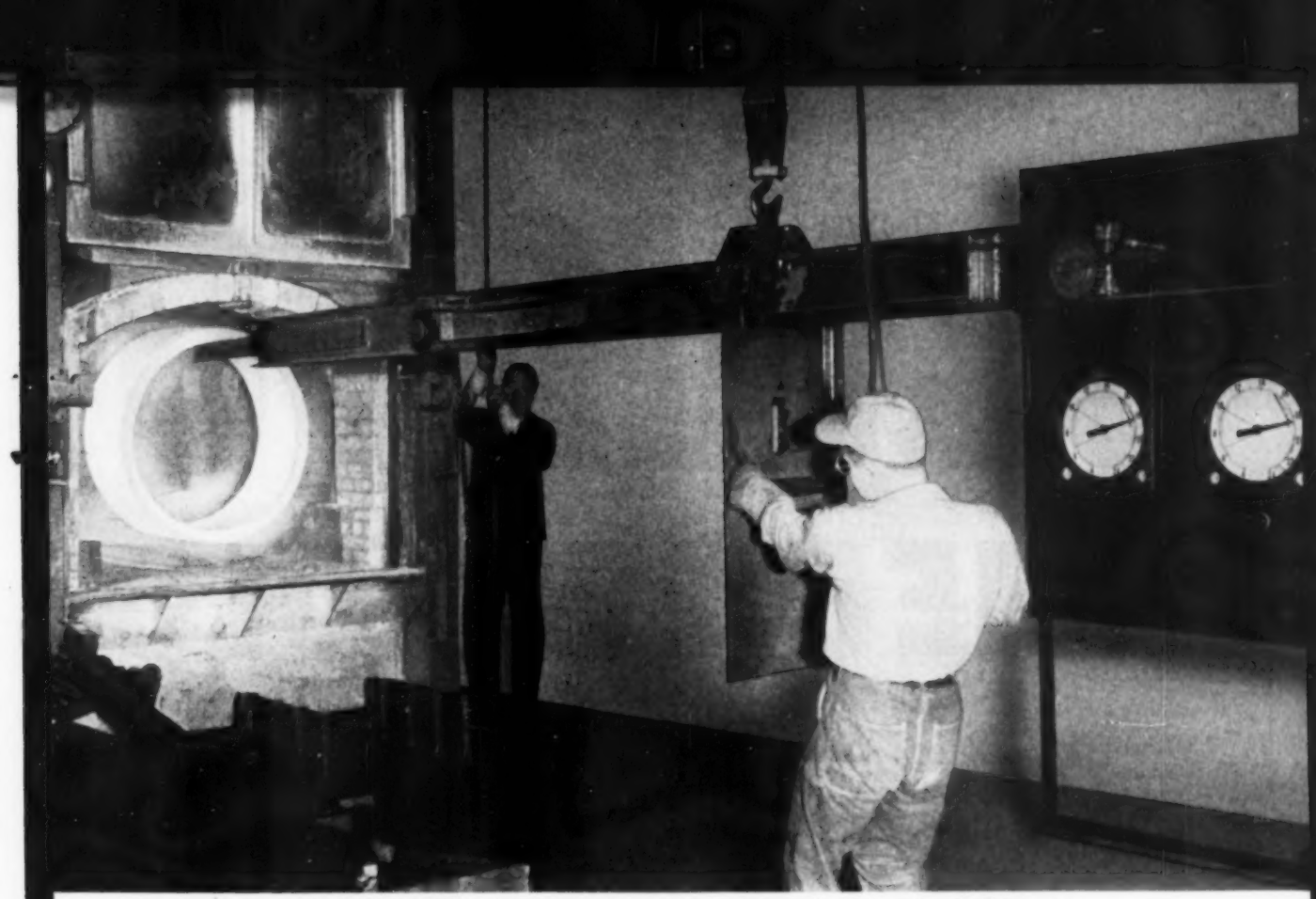
Honeywell application engineering covers the entire control installation. It works out details of what instrument to use for each measurement or control function . . . what type of primary element . . . what control system . . . what size and style of valve. It provides all essential signals, safety interlocks, and accessories. It combines all these elements into a complete unit, arranged for peak production efficiency . . . greatest convenience of the operator, and for maximum ease of service . . . custom-fitted to the individual needs of the process to be controlled.

**Saves Time . . . Produces Top Performance**

This Honeywell service gives specialized consultation on complex control problems that would otherwise require the attention of experts in the individual plant. But most important, it assures a control system that will produce the superior performance that Honeywell instruments are capable of giving . . . and which will help to obtain the most production and best quality from the process which it serves.

# For versatility *choose*

**SOUND PLANNING**, *based on specialized engineering experience, forms the basis of Honeywell Application Engineering. Here a round-table discussion between customer and Honeywell technicians irons out the initial control requirements for a process.*



**JET AIRCRAFT CASTING** *of stainless steel receives accurate annealing in a semi-muffle Drever furnace, at the Heat Treating Division of Drever Co., Philadelphia.* ***ElectroniK*** *instruments with Air-O-Line control regulate the two furnace zones to produce peak metallurgical characteristics.*

# in production heat-treating—

# *ElectroniK temperature control*

VERSATILITY is the keynote of the heat-treating service provided by Drever Company. Annealing, hardening, carburizing, nitriding, stress relieving and many other types of heat-treatment are performed here . . . on work ranging from tiny electrical parts to heavy forgings.

For these varied operations, temperature control has to be accurate. Electrical steels, for example, must be annealed in closely controlled atmospheres to maintain their magnetic qualities. Stainless steel parts demand precise treatment to produce exacting surface and metallurgical qualities. To assure the precision they need, Drever has equipped many of their furnaces with *ElectroniK* controllers.

No matter what the requirements of the job on hand, *ElectroniK* instruments hold furnace and atmosphere generator consistently at the specified temperatures . . . turning in the same high performance in Drever's own plant, as they do with Drever furnaces in scores of industrial installations.

Whatever your heat-treating problem, you'll find *ElectroniK* controllers afford the peak in precision, dependability and versatility. Models are available with a choice of electric or pneumatic control systems to fit any furnace. Your local Honeywell engineering representative will be glad to discuss your applications . . . and he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4503 Wayne Ave., Philadelphia 44, Pa.

● **REFERENCE DATA: Write for Catalog 1530, "*ElectroniK* Controllers."**

MINNEAPOLIS
**Honeywell**
BROWN INSTRUMENTS
*First in Controls*

# J&L "1200"

## THE NEW COLD

## ...that has shops

They're talking about results obtained with J&L "1200" Cold Finished Steel in terms of:

SUPERIOR MACHINABILITY
HIGHEST QUALITY FINISHES
DEPENDABLE UNIFORMITY

They're talking about actual production records that reveal:

EXCEPTIONAL EFFICIENCY
FOR MACHINES AND
OPERATORS

# STEEL

# FINISHED STEEL

*talking*

**J&L STEEL**

## J&L'S "1200" COLD FINISHED STEELS ARE RECOGNIZED

Equivalent compositions to the J&L "1200" series are published by the American Iron and Steel Institute, the Society of Automotive Engineers, and under Federal Specifications QQS-663.

However, evidence of *outstanding* performance is furnished by the records of shops who are using J&L's "1200" Cold Finished Steels in regular production runs.

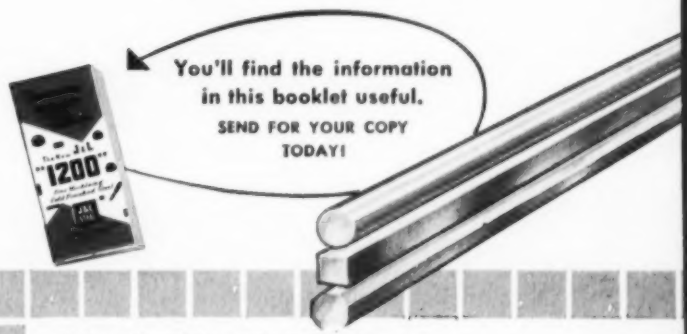
**JONES & LAUGHLIN STEEL CORPORATION**

PITTSBURGH

NOTE THE FOLLOWING EQUIVALENTS:

| J&L | Federal or AISI | SAE |
|---|---|---|
| J&L 1211 | C-1211 | 1111 |
| J&L 1212 | C-1212 | 1112 |
| J&L 1213 | C-1213 | 1113 |

## AVAILABLE IN ALL STANDARD SHAPES AND SIZES




**You'll find the information in this booklet useful.**

**SEND FOR YOUR COPY TODAY!**

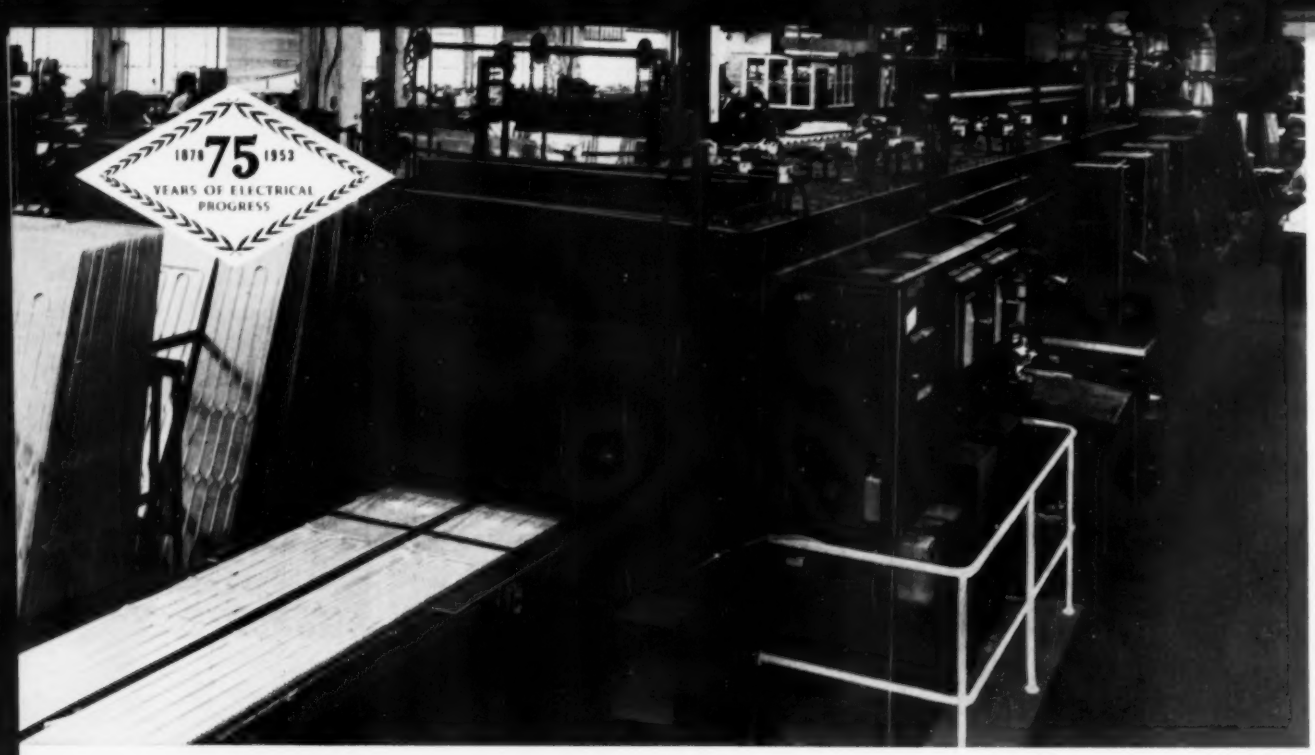
Jones & Laughlin Steel Corporation
405 Gateway Center
Pittsburgh 30, Pa.

Please forward a copy of your booklet, J&L "1200" Cold Finished Steel.

NAME _____

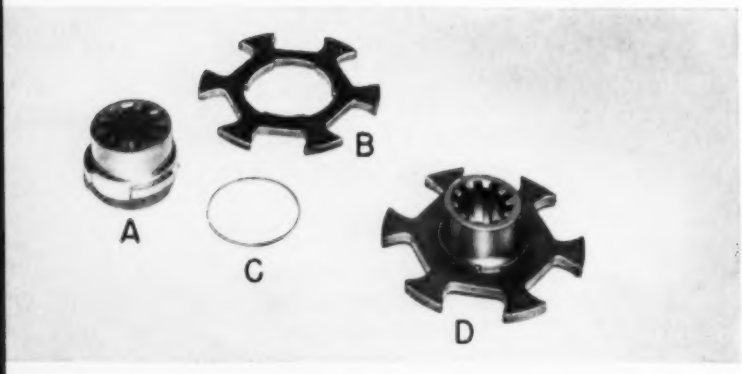
COMPANY _____

ADDRESS _____

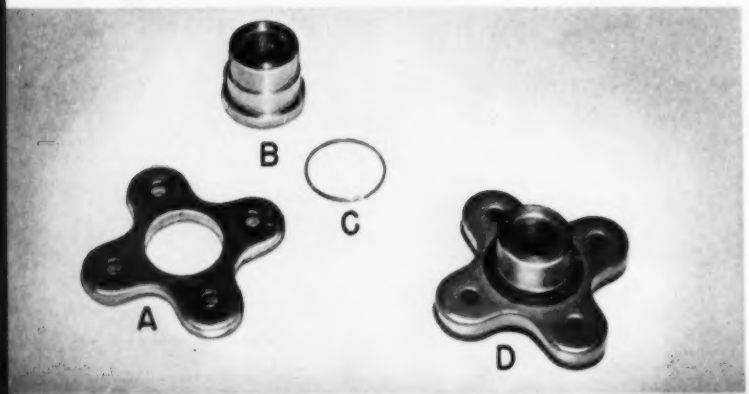



**1** **FURNACE BRAZING ALUMINUM ALLOYS** offers you many advantages: (1) cost is lower than either gas or arc welding, (2) brazed parts have a neater finish, (3) furnace brazing is easily adaptable to production line methods, and (4) sections too thin for welding can be brazed successfully. An increasing number of aluminum assemblies such as the refrigerator evaporators above are being fabricated by furnace brazing.

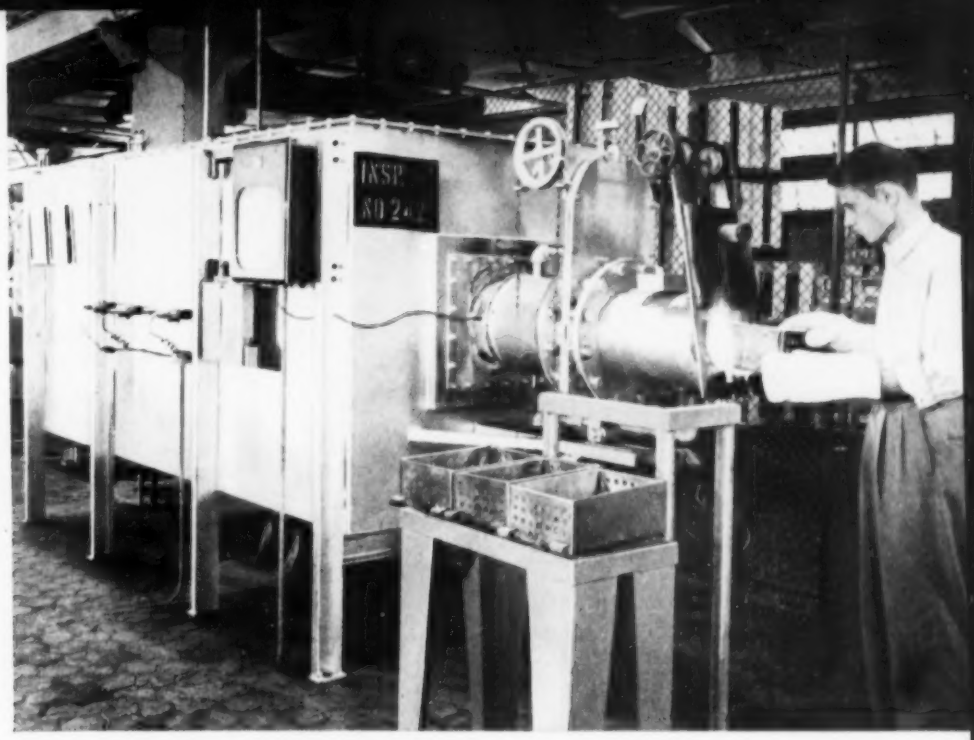
# Five Brazing Applications




**3** **SAVINGS OF 15 CENTS EACH** are reported on the fabrication of this clutch hub by furnace brazing. When formerly forged the assembly required expensive machining on the flange. For furnace brazing the operations are simple. The splined hub A is assembled with the punched flange B made from black hot-rolled steel, with the copper ring C placed at the joint. The hole in the flange is simply punched, with no reaming or broaching operation necessary. Serviceability of the furnace-brazed assembly is reported to be excellent.




**4** **SAVINGS OF 66⅔% IN MATERIAL** and 2½ cents on each pulley are the result of fabricating this assembly by furnace brazing. When formerly forged the part was cut from a section of bar stock about 2¾ in. in diameter and weighing about 1½ lbs. Now, in furnace brazing, parts made from blanks weighing only ½ lb are used. The process is accomplished by brazing punching A to screw machine part B with copper ring C to form assembly D.



**2 BRIGHT BRAZING STAINLESS STEEL** without flux in this semi-continuous furnace eliminates the characteristic green chromium-oxide and flux deposit. Because parts come out bright and shiny, no cleaning operations are necessary. Stainless assemblies such as the jet engine parts shown at left before and after brazing are brazed in protective atmospheres of pure dry hydrogen or dissociated ammonia in metal retorts.

# That Can Save You Money

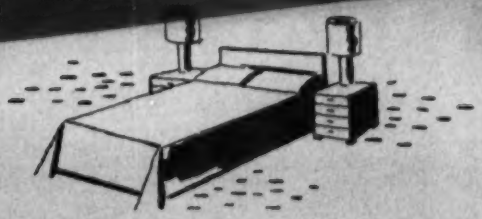
**5 INDUCTION HEAT FOR SILVER BRAZING** stainless steel helps this user increase production 50%, reduce rejects, eliminate leakers, and get uniformly stronger joints. Here, an operator brazes two stainless-steel nipples at a time into the stainless-steel head of a heater tank. Savings of 25% in silver solder are made possible with induction heat. Formerly, hand torches were used to perform this operation with non-uniform results and considerably more rejects.

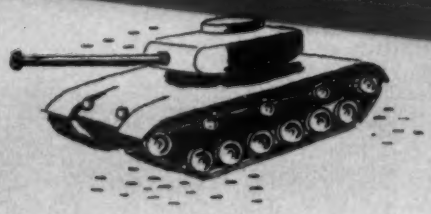
**For more information on how to apply brazing to your operations, contact the Heating Specialist in your nearest G-E Apparatus Sales Office. His years of experience involving every type of heating installation will be useful to you in solving your heating problems. General Electric Company, Schenectady 5, New York.** 725-10A

*You can put your confidence in—*

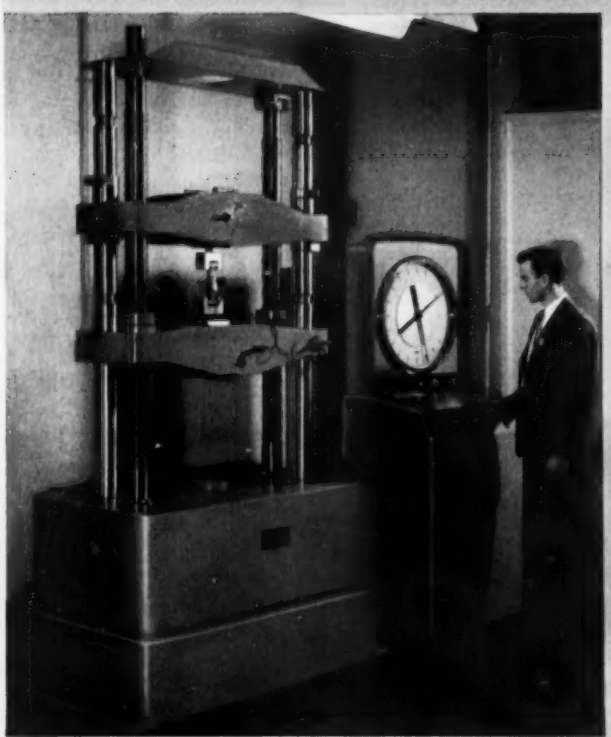
**GENERAL ELECTRIC**

# FROM BED SPREADS TO TANK TREADS





**You can test practically anything with a**



Tension test in progress on Riehle 120,000 lb. Hydraulic Universal. Photo courtesy of Cleveland Tank Plant, Cadillac Motor Car Division, General Motors Corporation.

# RIEHLE

## UNIVERSAL TESTING MACHINE

When you specify a Riehle Pendomatic, you're sure of getting a testing machine that is "universal" in every sense of the word. That's because every Riehle Pendomatic has 5 scale ranges, to provide complete coverage of the machine's full capacity. On the same machine you can test specimens with relatively low rupture points and you can also test high yield point specimens. All you do is turn the selector knob to the logical range and conduct the test. Guaranteed accuracy is within ½ of 1%.

### ILLUSTRATED CATALOGS

Riehle Universal Testing Machines are available either with hydraulic loading unit or with screw power loading unit, in all sizes up through 400,000 lbs. capacity. Ask your Riehle representative or write for illustrated catalogs.

## RIEHLE TESTING MACHINES

DIVISION OF AMERICAN MACHINE AND METALS, INC.
EAST MOLINE, ILLINOIS

"ONE TEST IS WORTH A THOUSAND EXPERT OPINIONS"

# engineering digest OF NEW PRODUCTS

## *Globar Melting Furnace*

The new Sentry electric furnace is designed for melting small crucible charges of various metals and alloys at temperatures to 2500° F. A cylindrical muffle chamber reduces the

tendency for fumes to enter the heating chamber and adversely affect the heating elements. Four silicon carbide rod-type resistors operate direct from a 220-volt supply.

**For further information circle #1282 on literature request card on p. 32B.**

## *Vacuum Testing*

New vacuum pump trucks just announced by the F. J. Stokes Machine Co. are compactly mounted on a fabricated steel base so that the entire unit can be transported by truck, fork truck or crane to any point where there is need for a vacuum system. They can be used as emergency equipment for the vacuum processing of a product or production materials or to test pipelines, vacuum and storage chambers, pumps and other equipment that must be vacuum-tight.

**For further information circle #1283 on literature request card on p. 32B.**

## *Roll for Hot Strip Mills*

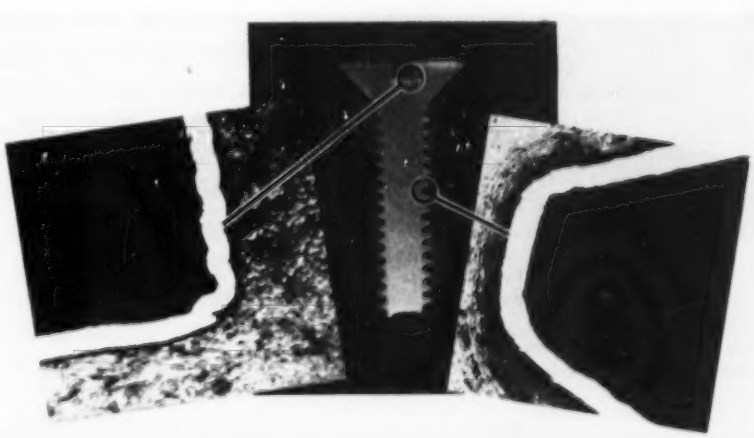
A new alloy iron roll, made by Mackintosh-Hemphill Co., is increasing roll time in strip mill finishing stands over 50% and in some extreme cases 200%. A modern 4-high hot strip mill normally consists of ten roll stands. The last six stands comprise the finishing train. In this finishing train, fully-alloyed, hard cast iron rolls, at 80 scleroscope hardness, have customarily been used in the last two or three stands. The preceding stands carry a low-alloyed roll at about 70 scleroscope. The new Mackintosh roll at 75 scleroscope is currently giving excellent service in the first two or three roll stands of the finishing train. Longer roll life between dressings means as much as 15 min. more rolling time every day, a total of 225 hr. per year for three stands. Thus, the extra tonnage produced on these rolls can amount to

## *Chemical Plating of Nickel*

General American Transportation Corp. has announced the availability of a new process of nickel plating which requires no electrolytic equipment. Named "Kanigen", it promises large economies in many industrial applications over customary methods, and in addition makes it possible to plate almost any solid substance with a dependable and predictable thickness of nonporous plate. The process has proved satisfactory for the production-line plating of steel, copper, brass, bronze, stainless steel and aluminum; tests on plastics and magnesium indicate that these materials will prove practical also. The new process will provide important savings in critical nickel; it is estimated that equivalent protection can be achieved with ⅓ to ½ the nickel required by other processes, partly because of Kanigen's nonporosity and partly because it plates so uniformly that it is unnecessary to overplate in places to assure ample over-all plating.

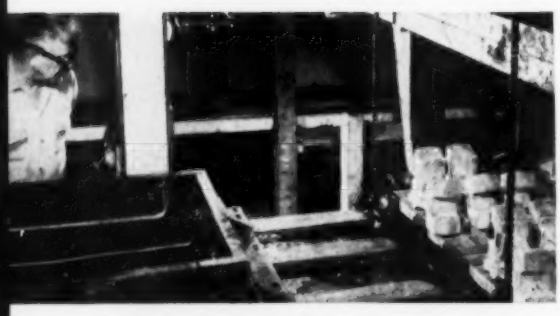
General American's research group succeeded in developing the Kanigen process through the reduction of nickel by the use of hypophosphites, a principle upon which the National Bureau of Standards had done considerable work several years earlier. Kanigen plate is a nickel–nickel phosphide composition, normally running about 5 to 8% phosphorus and having a Vickers hardness of 550 to 650. Its adhesion is excellent. Kanigen is usually within 5% of average thickness, while electrolytic nickel can run from 25 to 200% in variations between minimum and maximum. Kanigen's resistance to corrosion far exceeds that of electroplating in similar applications because of its nonporosity and thorough coverage, regardless of size, shape, indentations, or irregularities. In typical applications, even on a large scale, Kanigen is not likely to show any pores, even at plating thicknesses of 0.0005 in. Since neither design nor size offers any complications to the process, and because of the hardness of Kanigen plate, large vessels, tanks, chemical process equipment, valves, pipe structures and similar objects can be fabricated of any desirable and easily worked material, assembled, and then given a continuous coating of nickel in whatever thickness is desired. Thickness can be controlled to within 0.0001 in.

**For further information circle #1284 on literature request card on p. 32B.**



Picture shows how oil that forms sludge can clog cooler. Sun Quenching Oil's natural detergency helps prevent such sludge formation.

# Oil Coolers Don't Clog with

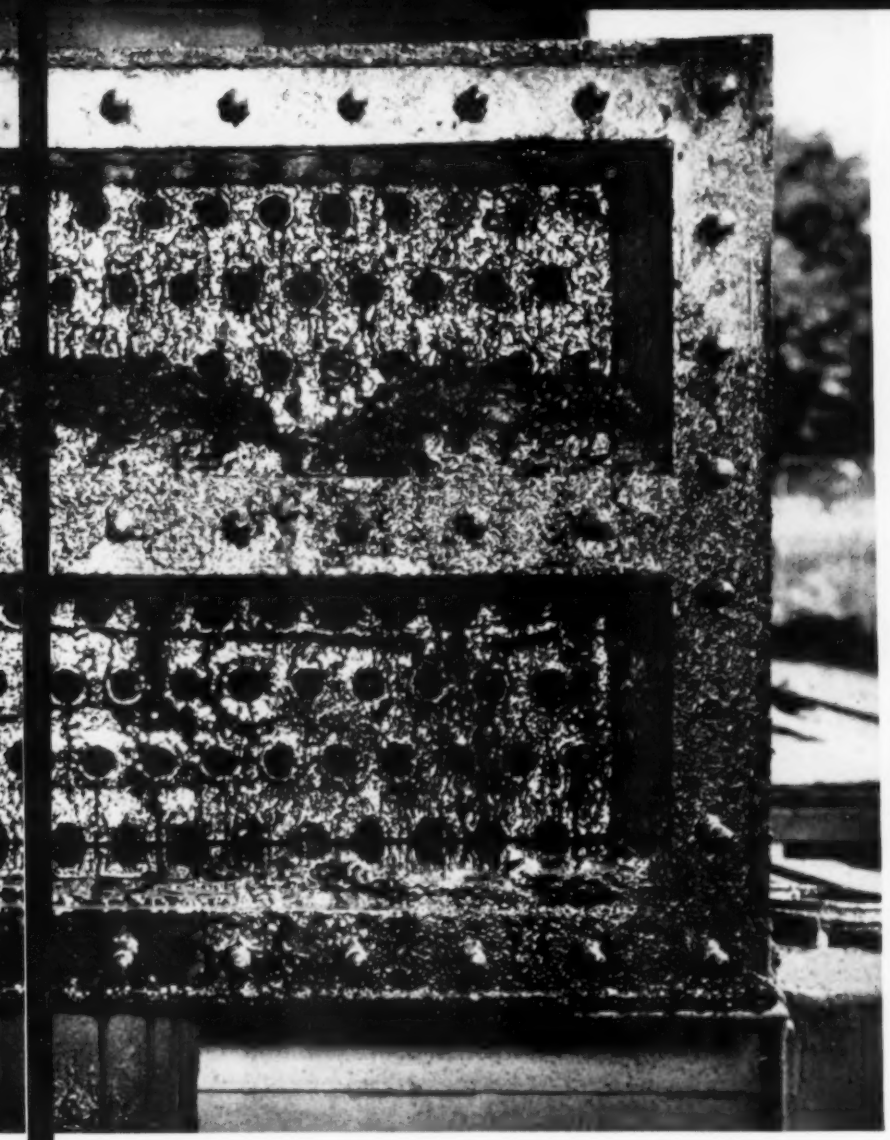


A New England firm uses five 2400-3000 gallon systems to quench all types and sizes of aircraft and automotive forgings. Since Sun oil was adopted 7 years ago, not one system has required cleaning except for normal removal of mill scale.

Sun Quenching Oils keep oil coolers clean. Teardowns are fewer and maintenance costs less. This is because Sun oils have a natural detergent action that prevents the formation of sludge and aids in removing any deposits that exist.

## Can Handle 95% of All Quenching Jobs

Tests show that Sun Quenching Oils give better all-around results. For one thing, they assure hardnesses far above the commonly accepted minimum requirements. In any system that provides normal agitation, they can handle 95 per cent of all quenching jobs.



# Sun Quenching Oil

**Sun Quenching Oils Reduce Operating Costs**
Sun oils thin out when heated, drain off parts faster and more completely. Dragout is reduced to a minimum. They do not thicken up, and under normal operating conditions need never be replaced. For more information about Sun Quenching Oils, call your nearest Sun office or write to SUN OIL COMPANY, Philadelphia 3, Pa., Dept. MP-5.

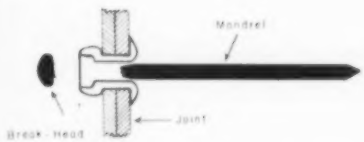
**INDUSTRIAL PRODUCTS DEPARTMENT**
**SUN OIL COMPANY**
SUNOCO

PHILADELPHIA 3, PA. ◆ SUN OIL COMPANY LTD., TORONTO & MONTREAL


67,000 tons per year, with a value of $4,700,000, for one modern mill.
**For further information circle #1285 on literature request card on p. 32B.**

### *Pop Rivet*

A rivet that cuts costs, makes "blind" spots as easy to handle as open sections and can be driven without a dolly has been introduced by J. C. Rhodes and Co. The rivet can be driven by inexperienced operators at a rate up to 1200 per hr. Known as a "pop" rivet, because of the speed with

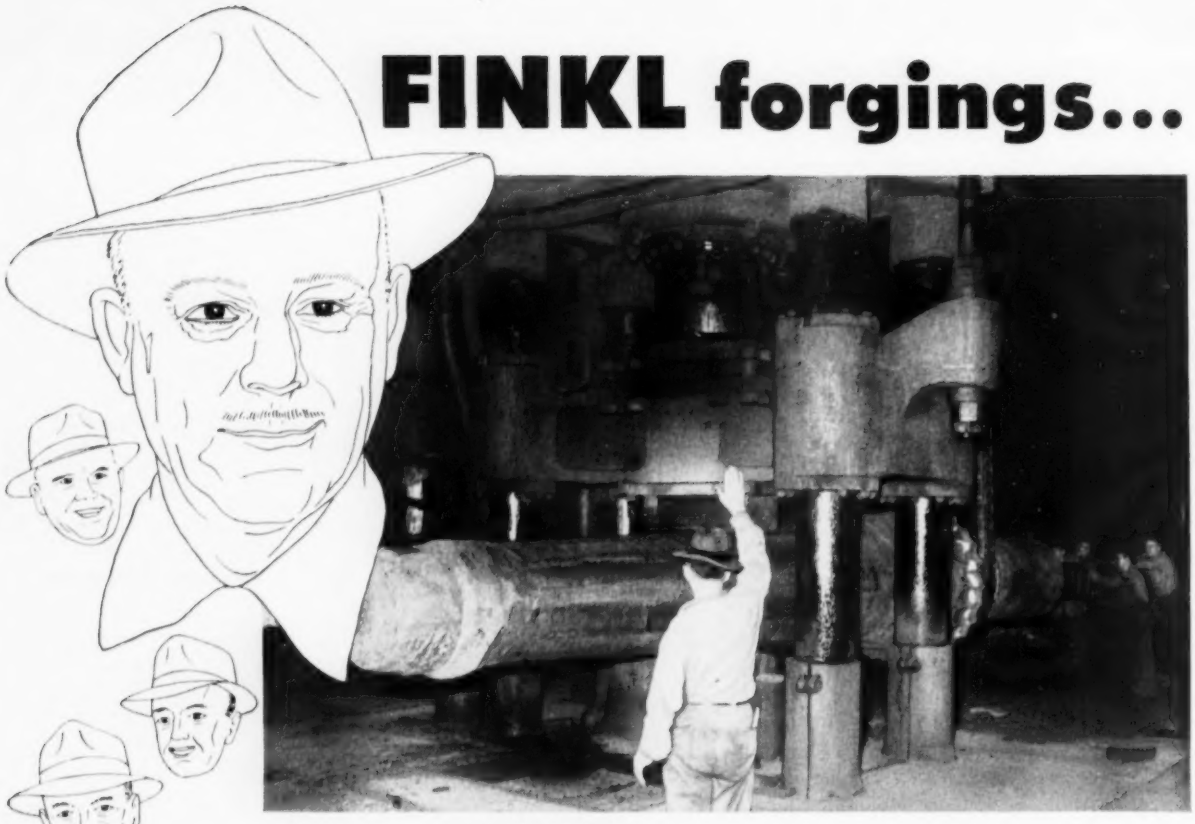



which it can be applied to the work, the fastener is available in Monel and aluminum. It consists of the rivet itself and an inserted mandrel of high strength steel, which looks much like a finishing nail. The mandrel is designed so that the head will break when the expansion has reached a point sufficient to provide maximum holding power. The head then falls off and the shank is pulled through the rivet. If preferred, the mandrel head may be retained in the end of the rivet, through the use of the break stem type of mandrel.
**For further information circle #1286 on literature request card on p. 32B.**

### *pH Meter*

Pocket-size pH meter and companion probe by Analytical Measurements, Inc., permit instant pH determinations

# FINKL forgings...



# ... and the MEN who make them

Meet Al, Don, Roy, Tony, Jack, Jim . . . Finkl press smith crews that make quality forgings and die blocks. Here, working with a 78,000 pound ingot of special analysis steel from Finkl's melt shop, these experienced men combine their skill and pride of workmanship to produce forgings and die blocks which prove that the finest product is the least expensive to you in the long run.

For **74 YEARS**, "Forgings by Finkl" has meant dependability and quality. For **74 YEARS** we have zealously guarded that reputation. And now, with complete control of quality from the analysis of the steel in our own melt shop through to the finished product, we can honestly say that Finkl forgings and die blocks are the finest available at the lowest cost to you.

**MANUFACTURERS OF THE LARGEST FORGINGS IN THE MIDDLE WEST**

## A. Finkl & Sons Co.

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**ELECTRIC FURNACE STEELS · DIE BLOCKS · FORGINGS**

anywhere. Completely self-contained with batteries, the instrument is furnished in a camera-type case with plastic tubes of buffer and KCl solutions. Total weight is 3 lb. The meter is scaled from 2 to 12 pH for easy reading. Accuracy of 0.1 pH is obtainable. Hearing-aid-type batteries provide up to 1300 hr. of operation.
**For further information circle #1287 on literature request card on p. 32B.**

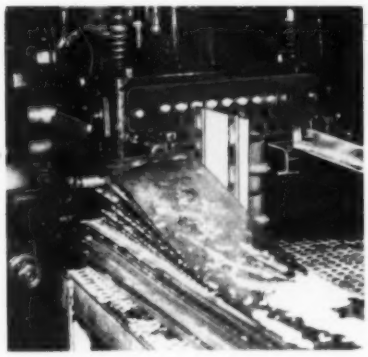
### *Ultra-Violet Inspection*

A new ultra-violet light for use as a portable inspection lamp, announced by Ultra-Violet Products, Inc., throws

a powerful directional beam of long wave (3660 Å) ultra-violet up to 30 ft.
**For further information circle #1288 on literature request card on p. 32B.**

### *Sheet Separator*

The bottleneck in press operations is often the slow job of an operator trying to pry apart steel sheets covered with grease. Using Basco mag-



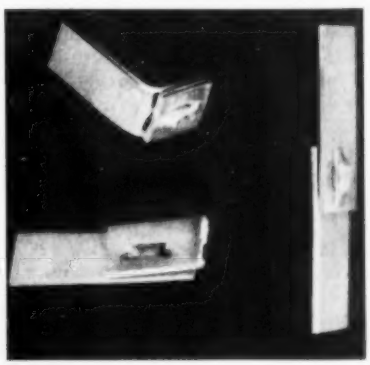
netic steel separators on the roll feed to the press, the steel sheets automatically fan out at the end, permitting the operator to grasp the top sheet easily and feed it into the press.
**For further information circle #1289 on literature request card on p. 32B.**

### *Protective Finish for Magnesium*

Allied Research Products, Inc., has announced Iridite 15 (Mag-Coat), a new protective finish for magnesium. This is a chromate conversion coating; it converts the surface of treated magnesium to a new, and chemically different, surface. Dark brown in color, the film is highly resistant to atmospheric corrosion, as well as to corrosion from some chemical sources. The film is produced by simply immersing the parts in a solution at room temperature, without electric current. Immersion times vary from 15 to 120 sec., depending on the condition of the metal prior to treatment, the alloy treated, and dimensional stability required.
**For further information circle #1290 on literature request card on p. 32B.**

### *Fastening Method*

A revolutionary one-step method of fastening sheet metal, called Metalacing, literally buttons metal to metal—without any additional element such as rivets, bolts, welds or solder. It accomplishes this in a single operation with a patented punch and yieldable die, made in a range of sizes that will fasten sheet metal up to ¼ in. thick. Any punch press may be converted to Metalacing duty merely by inserting the special punch and die.



The Crockatt Engineering Co. has sole rights to license the new development.

Success of the new method stems from three separate operations that take place during the impact of the punch on the metal and the patented die. First, shearing action of the punch and die creates a parallel double incision in the two sheets of metal being fastened. Metal between these incisions is rammed downward, against the anvil of the die beneath the sheets and between the die's movable jaws. There the force of the impact spreads the depressed metal sideways, making it form a permanent fastening wedge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of this versatile steel. 52100 is hard, tough and long-wearing, yet it's easy to machine and is right for bearings, sleeves, pins, collars and many other machine parts.

Over 200 seamless tube sizes to choose from .898" O.D. to 8.250" O.D. Bar sizes from .171" round to 7.5" round. Also ring forgings in any analysis.

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DEPT. M. SPRINGFIELD ROAD
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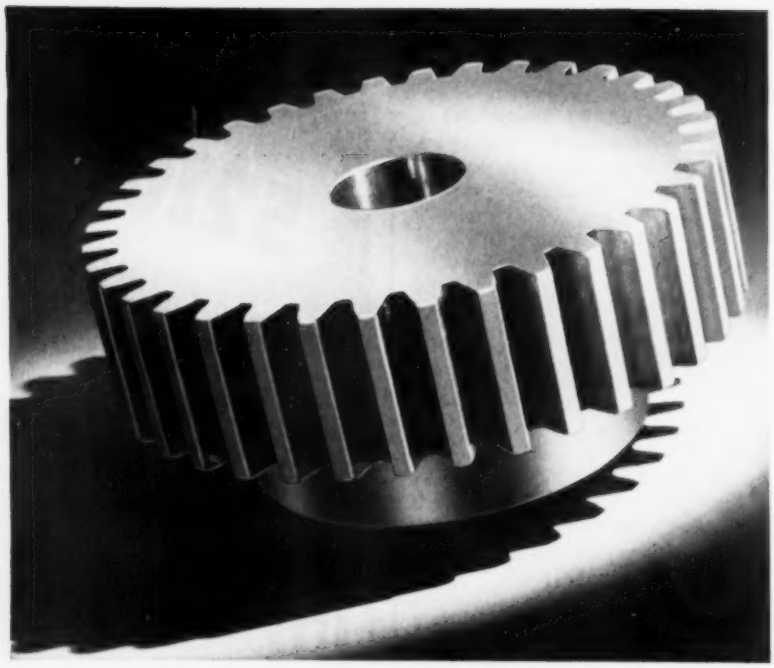

# High lustre finish... faster with SUPER-HONITE CHIPS!

**YES!** New Super Honite gives a better finish —*faster*—than any other barrel finishing abrasive. That's because it's the world's *toughest* abrasive chip—engineered for grinding and burnishing to a high luster finish. Does it in jig time, too, because chips don't crumble or pulverize to slow the job.

So remember, for a better finish—in record time—specify Super Honite. No other chip cuts faster—no other chip cuts as long!

**TOUGHEST NATURAL CHIP!** Use Regular Honite for close tolerance work or minimum removal of metal. No other barrel finishing abrasive—not even granite—retains its edge as long as Regular Honite.

WRITE TODAY for your free copy of "3M Barrel Finishing" . . . it's filled with helpful information for increased efficiency, lower costs. Address Minnesota Mining & Mfg. Co., Dept. MP53, St. Paul 6, Minnesota.

Name.....

Company.....

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City.....Zone...State.....

Honite BRAND

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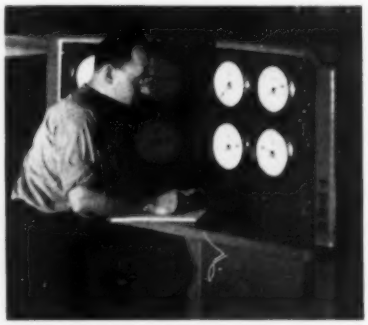
3M COMPANY


or button under the surface of the bottom sheet. Thus the parent metal itself — not any additional element such as a rivet, bolt or staple — supplies the fastening.

**For further information circle #1291 on literature request card on p. 32B.**

## *Spectrometer*

Baird Associates direct-reading spectrometer is a fully automatic control-analyzer for melt shop production,

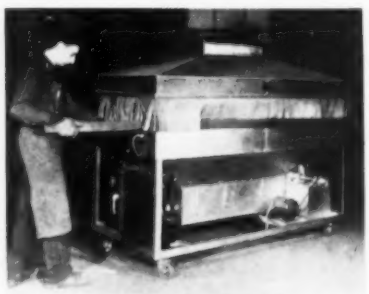


which handles up to 30 elements in less than a minute.

**For further information circle #1292 on literature request card on p. 32B.**

## *Aluminum Bar Heating*

To fulfill the needs of the aircraft industry to heat special aluminum bars to approximately 300° F., prior to forming operations, the Pereny Equipment Co. has introduced a portable electric furnace. This unit, having an oven size of 3 by 6 ft. and 8 in. high, has a blower for recirculation of the



heated air. A semi-closed opening for feeding and discharging the long bars is provided by means of an asbestos strip curtain. The unit is mounted on rollers so that it can be transported to the immediate location of the forming operation.

**For further information circle #1293 on literature request card on p. 32B.**

## *Cold Chamber Die Casting*

A cold chamber die casting machine by Lewis Welding & Engineering Corp. introduces a new principle of injection

# New facts for your file on U·S·S CARILLOY STEELS

## In parts for rotary drills pre-hardened, free-cutting Carilloy FC steel

A drill and a drill box, one at either end of these 20-ft. rotary drill rods, are used to connect the rods. In the close-up, the box-ends of two rods are shown at the left and the pin end of another rod at right. These coupling devices cost 12% less and are easier to machine, now that they are made from U·S·S Carilloy FC steel.

Gill Rock Drill Co. now machines drill boxes and pins without sending the steel out for heat treatment before and after rough machining. Elimination of this extra heat treatment prevents production delays and cuts costs.

The drill box, left, and the drill pin, right, are made from 4¾" to 5½" Carilloy FC steel rounds. This pre-hardened, free-cutting steel provides the needed strength and toughness for these heavily-stressed parts.

### . . . eliminates two heat treatments

### . . . machines easily

### . . . cuts costs 12%

● At Gill Rock Drill Co., Lebanon, Pa., pins and boxes for heavy duty rotary drills are turned, drilled and threaded from U·S·S Carilloy FC steel *without* any additional heat treatment. This steel comes from the mill ready to use—hardened to 321 Brinell and with good machinability.

The alloy steel formerly used for these drill pins and boxes had the needed strength and toughness; but it had to be sent out for heat treatment before and after machining. This took a lot of time . . . and it cost money.

Now made from Carilloy FC steel, these parts are machined *completely* without further heat treatment, are easier to machine, meet all the high quality specifications, and cost 12% less than before. Carilloy FC is performing so well in pins and boxes that it is now being used for rotary drill collars as well.

It will pay you to investigate the possibility of using Carilloy FC steel for your products. It comes in all standard bar forms and sizes, quenched and tempered to a hardness from 255 to 375 Brinell. Tensile strengths range from 125,000 to 175,000 psi. Our experienced metallurgists will be glad to give you complete details. Just write to United States Steel, 525 William Penn Place, Pittsburgh 30, Pa.

USS

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TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA. · UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS, COAST-TO-COAST
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UNITED STATES STEEL

# "I've got 90 years'

## says Ernie Stevens, U·S·STEEL HEATER

As a Heater at our Homestead Forgings Division, Ernie operates the 49-foot car-bottom furnace that heats the ingot up to forging temperature.

He has worked at Homestead for 40 years, and his father was a Heater, too—for over 50 years. When Ernie was 18, he knew more about heating steel than most men, just from talking to his father. That's why, today, he can draw upon 90 years of experience in the forge shop.

When an ingot comes from the melt shop, Ernie puts it in his furnace and "equalizes" it so the temperature will be the same all the way through. Then he slowly raises the piece to the right forging temperature. These operations require that Ernie use his skill and experience to heat the ingot uniformly to insure successful forging.

But that's not all of the job. Say a Pressman finished forging *one* end of a piece, then sent it back for a re-heat before working the *other* end. Ernie puts the piece in one of his furnaces, then carefully adjusts the gas burners to control the temperature on the finished end, and still heat the unfinished end to the proper forging temperature.

Obviously, there are many heating techniques a Heater must use. Yet, heating is a completely reliable operation at our Homestead Forgings Division because all of our Heaters, like Ernie, have the experience, the equipment, and the firm determination to give you the finest forgings that money can buy.

Why not make use of this experience on your next forging order? For more information on U·S·S Quality Forgings or for our new 32-page booklet describing them, write to United States Steel, 525 William Penn Place, Room 2811-U, Pittsburgh 30, Pa.

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Quality FORGINGS

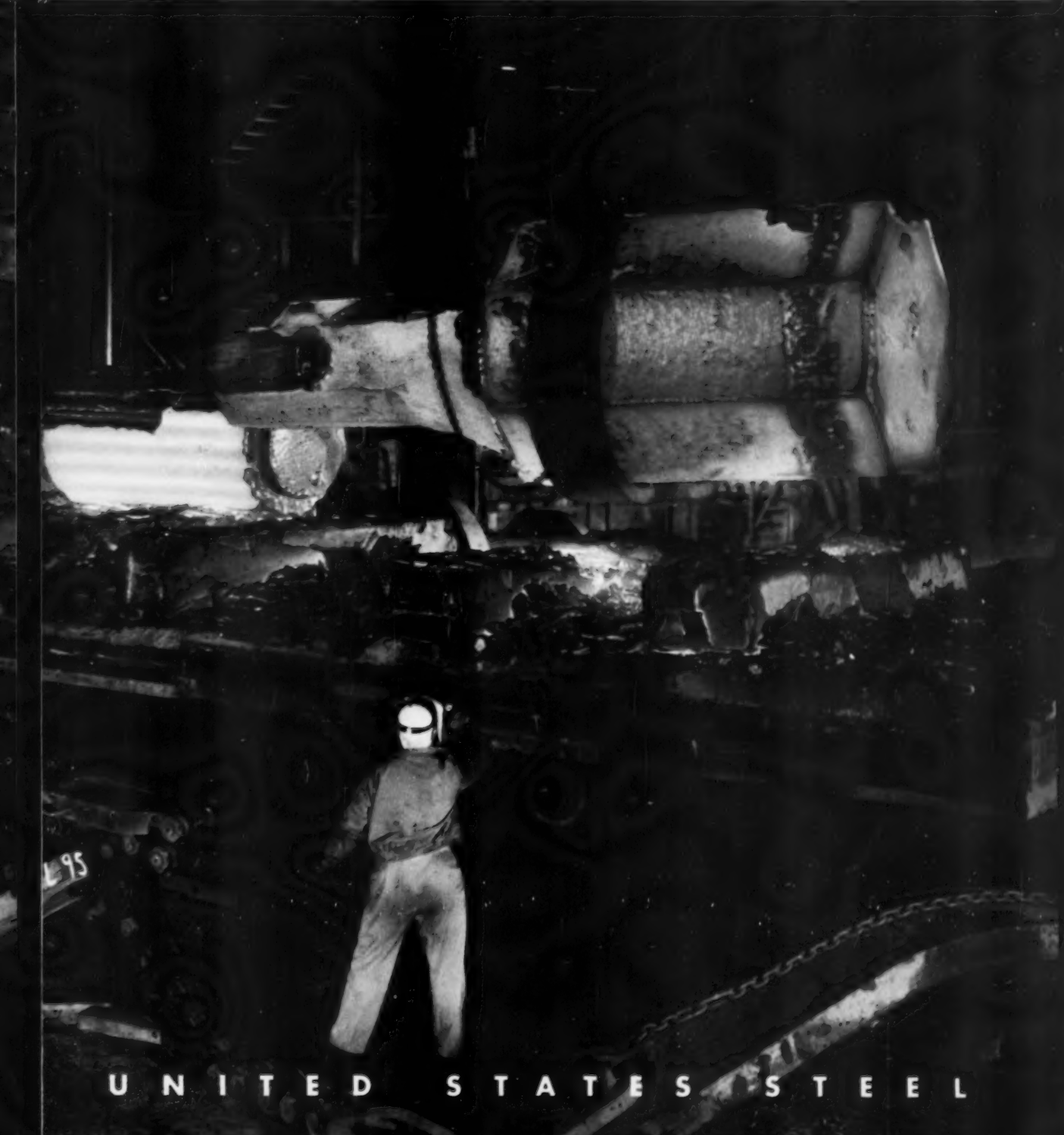
heavy machinery parts—carbon, alloy, stainless

electrical and water wheel shafts

hammer bases and columns

marine forgings

**experience in heating steel!"**



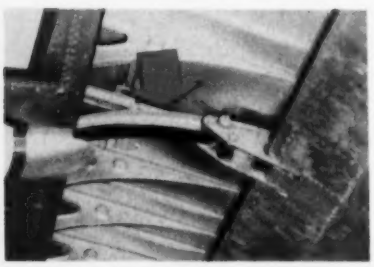
UNITED STATES STEEL

# New facts for your file on U·S·S CARILLOY STEELS

## U·S·S Carilloy steel in rolled sections

## lops 4 hours off machining time, provides stronger flap tracks for Convair airliners and cuts costs 75%

Landing flaps on the Model 340 Convair airliner slide on tracks made of CARILLOY 4140 steel T-sections. These tracks are much stronger than those formerly made from rectangular bars. And they cost 75% less!



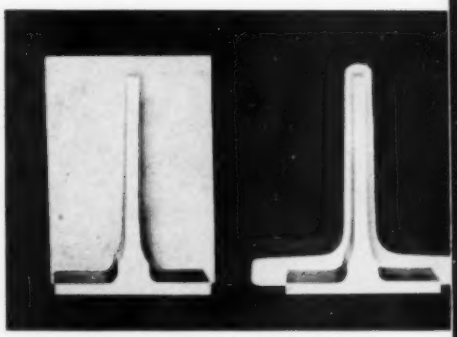
● Wing flap supports for Consolidated Vultee's Model 340 Convair airliners are stronger, cost *less*, and are of better quality now that they are made from hot-rolled sections of U·S·S CARILLOY steel.

When J. C. Peacock Co., of Los Angeles, California, started making these T-shaped flap tracks for Convair, the accepted practice was to machine them from $2\frac{1}{4}$" x $3\frac{1}{4}$" bars of alloy steel. But machining took a lot of time, and more than 50% of the stock metal was wasted in scrap.

Peacock and Convair engineers studied the problem and soon realized that they could shorten machining time and reduce scrap losses by fabricating directly from rolled sections. The question was, where to find a good supply of steel that would meet all the exacting quality requirements. U.S. Steel came through for them, by providing hot-rolled T-sections of CARILLOY 4140 steel.

This steel is giving excellent results. Not only are the CARILLOY parts *stronger* than those formerly used, but they require 4 hours less machining time, and reduce scrap losses 60%. What's more, finished tracks now cost only *one-fourth* as much as they did before.

Our experienced metallurgists may be able to help you make similar savings on *your* products. Call our nearest District Office. Chances are, we can supply just the steel and the form you need.



LEFT, the T-shaped cross-section of a flap track in front of a $2\frac{1}{4}$" x $3\frac{1}{4}$" steel bar shows how much metal was formerly wasted. RIGHT, the same flap track in front of the CARILLOY T-section that cuts scrap loss 60%.

### U·S·S CARILLOY STEELS ARE PRODUCED IN THE WIDEST AVAILABLE RANGE OF ANALYSES, SIZES, FORMS, HEAT TREATMENTS, AND TO HIGHEST QUALITY STANDARDS

● Complete, *integrated* alloy steel producing and finishing facilities make it possible to furnish CARILLOY steels to meet practically any requirement.

If you need forging ingots, blooms, billets or slabs . . . square bars, round bars, coiled bars, spring flats or special sections . . . plates, sheet, strip, sketch plates or structural shapes—

If you use bearing steel, aircraft steels, gear steels . . . NITRALLOY steels . . . regular or special analysis alloys—

If the steel must be quenched and tempered . . . regular or spheroidized annealed . . . normalized . . . stress relieved or tempered . . . or needs other special heat treatments—

If you want it hot rolled . . . in straight lengths or coiled . . . machine or gag straightened . . . flattened . . . machine, cracker or torch cut . . . pickled . . . sand blasted, oiled or limed—

Whatever your specifications call for —we can provide.

### Free metallurgical assistance available on any steel problem

**To help you use CARILLOY steels most efficiently, we place at your disposal the best metallurgical talent available. These men—many of them recognized authorities in the field of steel metallurgy—can call upon the facilities of the most extensive steel research laboratories in America. Their recommendations to you can be entirely unbiased because they have the most comprehensive range of metallurgy's finest quality steels from which to fill your needs.**

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UNITED STATES STEEL

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## MAGNAFLUX* Goes Anywhere with NATIONWIDE COMMERCIAL INSPECTION SERVICE

This MAGNAFLUX-OWNED AND OPERATED SERVICE offers you *all* the inspection methods and facilities of Magnaflux Corporation to detect defects in any metal part, and ceramic or plastic materials.

By revealing defects *before* they waste materials and manpower, or cause unplanned shutdown of machines and equipment, Magnaflux Commercial Inspection is achieving major savings for hundreds of companies... all over the country.

*Magnaflux and Magnaglo are registered trade marks of Magnaflux Corporation.

Magnaflux Field Inspection Truck goes down to turbine room floor on inspection assignment.

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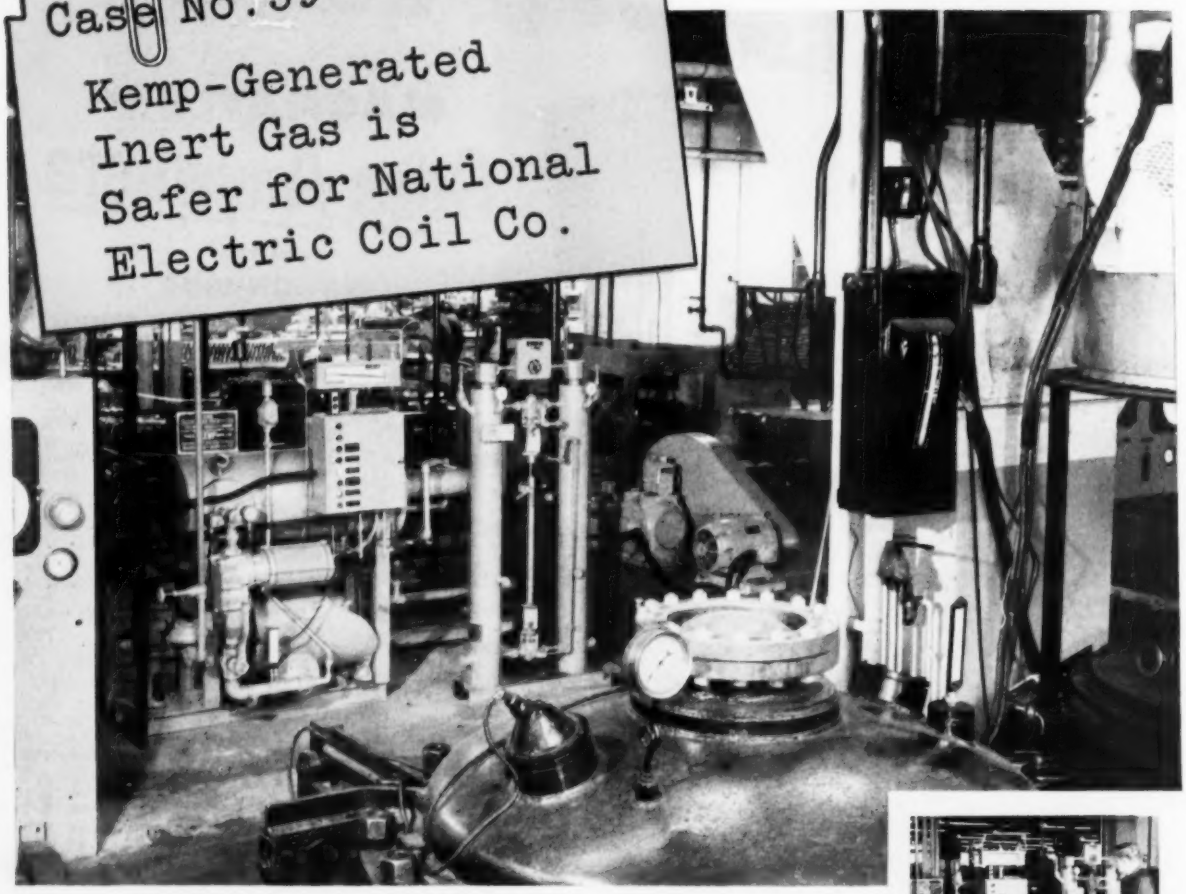
Case No. 59

# Kemp-Generated Inert Gas is Safer for National Electric Coil Co.



## How National eliminates danger of explosion . . . cheaply and conveniently

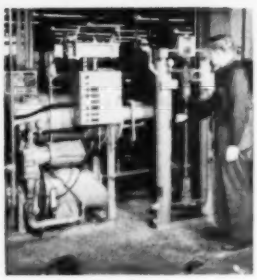
National Electric Coil Co., Columbus, Ohio, impregnates electric coils and windings by forcing in a hot sealing compound with inert gas under pressure. Formerly, the Company used air under pressure, but this created an explosion hazard. National then switched to $CO_2$ generated by melting dry ice. Although this decreased the danger factor, it was an extremely expensive operation and very inconvenient. To modernize this process and cut costs, National installed a Kemp Gas Generator, Model MIHE.

### Kemp Solved the Problem—and More

Now National's Kemp installation delivers a completely satisfactory inert—eliminating any danger of explosion. And it delivers it at a *much lower cost* than the former generating method. In addition, Kemp supplies the gas at the rate required, plus a reserve for storage. As for convenience, the company considers their unit entirely automatic—it is practically never touched. According to Mr. D. E. Stafford, Chief Engineer, "It just sits there and operates."

### Kemp Can Solve Your Problem Too

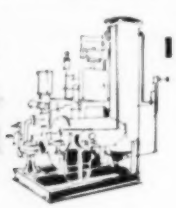
Every Kemp Generator is engineered for fast-starting, easy operation that saves both *time* and *money*. Kemp equipment delivers a chemically clean inert at a specific analysis . . . without fluctuations regardless of demand. And every Kemp design includes the latest firechecks and safety devices. For convenience, safety, and cleaner, more dependable gas—specify Kemp.



Mr. Wm. C. Graessle, of the engineering department, checking the operation. Generator features the Kemp Carburetor, part of all Kemp equipment, to deliver complete combustion . . . without waste, without tinkering.

*For more complete facts and technical information, write for Bulletin I-10 to:* C. M. KEMP MFG. CO., 405 East Oliver Street, Baltimore 2, Md.

**KEMP OF BALTIMORE**



**INERT GAS GENERATORS**

CARBURETORS • BURNERS • FIRE CHECKS
METAL MELTING UNITS • ADSORPTIVE
DRYERS • SINGEING EQUIPMENT

which provides for rapid fill while the metal is molten, and unusually high final squeezing pressure. This prevents shrinkage voids as the metal freezes and excessive porosity due to gases being trapped in the dies. The Lewis machine also features a new method of clamping the dies together, known as Hydra-Lock, which develops a final clamping pressure of 650 tons. This high clamping pressure is necessary to resist the high injection pressures which the machine can develop, 100,000 lb., accomplished by a special hydraulic two-stage injection system.
**For further information circle #1294 on literature request card on p. 32B.**

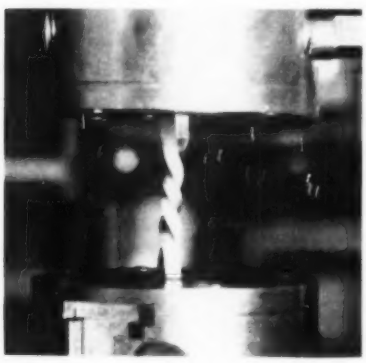
### *Portable Sandblaster*

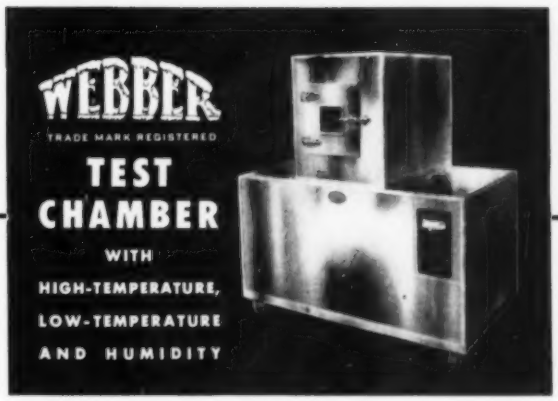
A new portable sand blasting machine has been announced by The Corson Co. The machine uses any clean dry sand that will pass through a 16-ga. screen, metal shots, grit or finer sand blast sand. It operates from any direct air line or compressor having 80 lb. or more pressure, and the average air consumption is 30 to 35 cfm. depending on nozzle size and air pressure used. The machine is available in three models with sand capacities of 90, 150 and 200 lb.

**For further information circle #1295 on literature request card on p. 32B.**

### *Powder Metal Product*

A new iron powder metal product, Steel Oilite, by Amplex, has several times the ductility of previous iron powder products. It has physical properties comparable to mild carbon steel, such as 1010 to 1030, and can be used for finished machine parts such



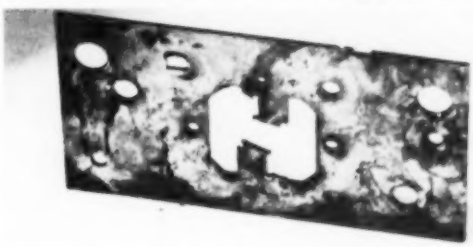




★ This Webber test unit, designed for production and experimental testing, has a temperature range from +250°F., to −100°F. The pull-down to −100°F., is achieved in 45 minutes, and can be cycled from −100°F., to +250°F., in 30 minutes. 95% relative humidity is provided at temperatures between 75°F., and 95°F. Vacuum equipment can be added to simulate high altitudes. The test chamber, provided with a moisture-proof light for illumination, is 4½ cubic feet, 20 inches high, 20 inches wide, 20 inches deep. High and low temperatures are governed by a temperature controller with scale range from −200°F., to +400°F., with a 3 degree control point differential, 1½ degrees plus and minus. The humidity is regulated by a wet and dry bulb controller. Unit size is 60" long, 45" wide, 74" high. Apertures in left side of cabinet provide for electrical cables to energize equipment being tested. Webber offers a complete line of test units for various applications.

*Write for more complete information*

INDUSTRIAL FREEZER DIVISION
**WEBBER APPLIANCE CO., INC.**
2740 MADISON AVENUE • INDIANAPOLIS 7, INDIANA

*13,500,000 Blanks with Darwin & Milner's* NEOR *Die Steel*



This NEOR Lamination Die to start measured 1 x 3½ x 6¼ in. Average run of this die, blanking silicon sheet steel, was 90,000 to 100,000 blanks per grind of die. 12,000,000 pieces were blanked out, when superintendent furthered service by holding die in press with clamps—adding at least 1,500,000 pieces. When finally unfit for further use, the die was 3/32 in. thick. *Punch also was made from* NEOR.

ESTABLISHED 1911
ZIV STEEL & WIRE CO.

ZIVCO TRADE MARK
2945 W. HARRISON STREET • CHICAGO 12, ILL.
BRANCHES
DETROIT, MICH. • ST. LOUIS, MO. • MILWAUKEE, WIS.
INDIANAPOLIS, IND. • TOLEDO, OHIO • EAGLE RIVER, MICH.

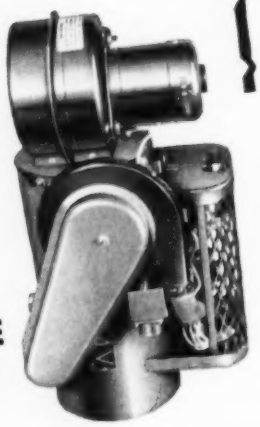
# Sicon

*The Original*

**SILICONE HEAT-RESISTANT FINISH**

***Withstands 500° F. in Color Application***

SICON
Olive Drab
Adopted by
STEWART-WARNER
for
ARMY ORDNANCE
Truck Heater Shells



SICON SILICONE FINISH

CONVENTIONAL FINISH

These two heater shells were subjected by Midland Engineers to a 500°F. heat test, for four hours, followed by a 300 hour salt spray test conforming to ASTM B117-49T. SICON retained color, gloss, adhesion. A widely used specification finish for this purpose failed completely. The pictures tell the story.

**ACTUAL TESTS PROVE SICON'S SUPERIORITY**

It was felt that army ordnance requirements for truck heaters demanded an olive drab protective finish that would withstand temperatures of approximately 500° F., followed by a salt spray test. SICON was tried and is being used by Stewart-Warner in production because it met these rigorous demands.

If you require a finish in a *decorative color* with specific heat resistant properties, SICON, the original Silicone-Base Heat Resistant Finish, may be the *only* finish that will do the job. It will pay you to investigate. Write for illustrated brochure without obligation.

*Manufactured by*

**MIDLAND INDUSTRIAL FINISHES CO.**

WAUKEGAN, ILLINOIS

ENAMEL • SYNTHETICS • LACQUERS • VARNISHES

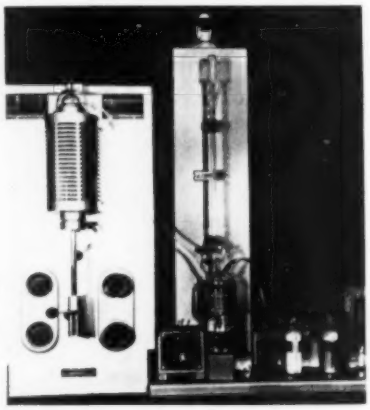
Sicon


as gears, cams, brackets and lever arms that heretofore have been of sufficient strength only when made from forgings or bar stock. It is not intended for self-lubricating parts.

**For further information circle #1296 on literature request card on p. 32B.**

### *Carbon-Sulphur Analysis*

Carbon and sulphur contents in all types of ferrous alloys can be determined by means of a new procedure introduced by the Laboratory Div., Lindberg Engineering Co. The new

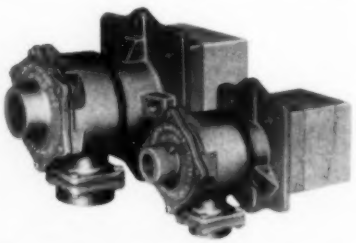


unit, which employs radio frequency induction heating, tests for both carbon and sulphur in a single operation in 10 min. Samples can be heated to temperatures above 3000° F., substantially higher than previously practical with resistance element furnaces.

**For further information circle #1297 on literature request card on p. 32B.**

### *Gas Burner*

North American Mfg. Co. has introduced a new, nozzle-mixing type of gas burner having a high effective turndown, making it ideal for installation on multiple-purpose furnaces.



A furnace equipped with these burners can be operated at temperatures from 400 to 1800° F. The burners may be operated with air pressures from 0.1 to 16 oz. at the burner, giving a wide choice of capacities from 28,000 to 2,620,000 Btu. per hr.

**For further information circle #1298 on literature request card on p. 32B.**

# WHAT'S NEW

## IN MANUFACTURERS' LITERATURE

**1299. Abrasive Cutting**
20-page booklet 6, "Metallic Cutting Off With Abrasive Wheels". *Abrasives Div., Carborundum Co.*

**1300. Air-Gas Mixer**
Bulletin L-700 gives engineering and application data on air-gas proportional mixer. *Eclipse Fuel Engineering*

**1301. Alloy Castings**
22-page bulletin 2041 on heat & corrosion resistant castings. *Blaw-Knox*

**1302. Alloy Castings**
Property data for 21% Cr, 9% Ni heat-resistant alloy. *Electro-Alloys Div.*

**1303. Alloy Hearth**
Bulletin 112 on cast Ni-Cr hearth for heat treating furnaces. *Fahralloy*

**1304. Alloy Steel**
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

**1305. Alloy Steel**
40-page book on heat treated alloy steel plate for maximum abrasion and impact resistance. Details on uses; 12 pp. of technical data. *Jones & Laughlin*

**1306. Alloy Steel**
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

**1307. Alloy Steel**
Data folders on two types of alloy steel castings. Composition, properties, hardenability bands, uses. *Unitcast*

**1308. Alloy Steel**
68-page "Aircraft Steels" booklet includes revised military specifications. Also stock list. *Ryerson*

**1309. Alloy Steel**
16-page booklet, "Alloy Steels and How to Get the Most Out of Them", contains seven case histories selected from widely varied fields. *Republic Steel*

**1310. Alloy Tools**
44-page book on cast Stellite tools for metal cutting. *Haynes Stellite*

**1311. Alloys**
24-page book on alloys for adding to ferrous and nonferrous melts. *Alter Co.*

**1312. Aluminum Alloys**
36-page book on analysis of aluminum, brass, bronze alloy specifications. *Sonken-Galamba Corp.*

**1313. Aluminum Bronze**
Engineering manual on wrought forms of aluminum bronze. *Mueller Brass*

**1314. Aluminum Bronze**
Data sheets for aluminum bronze coated electrodes for welding. *Weldwire*

**1315. Aluminum Castings**
Bulletin on quality control methods in making aluminum castings. *Permold*

**1316. Aluminum Die Castings**
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

**1317. Aluminum Extrusions**
28-page book on extruded aluminum products. Design, tolerances, applications. *Revere*

**1318. Aluminum Extrusions**
Data on services in the field of aluminum extrusions. *Himmel Bros. Co.*

**1319. Aluminum Heat Treating**
8-page Bulletin 5912 on solution heat treating, annealing, stabilizing and aging of aluminum. *General Electric*

**1320. Ammonia Dissociators**
Bulletin on dissociating process gives advantages of ammonia as controlled atmosphere. *Sargeant & Wilbur*

## *1321. Wear and Surface Finish*

"Wear and Surface Finish"* will be greatly appreciated by the designers and makers of all those products which have bearings or other friction surfaces. This excellent book of 80 pages is a valuable short course for those who wish to have more expert knowledge on this subject. Its author, E. L. Hemingway, Research Engineer, has presented the subject concisely, completely and with documentation. He has included fundamental data usable in design and conclusive tests reported in a readable and comprehensive manner.

Theme of the book is that wear is not a "necessary evil". The author demonstrates that wearing consists of minute welds at surface high points which exert high unit pressures and break through the oil film. This contention is supported by applicable test results and photographs.

The nine major subject headings are (1) Measurement of Surface Roughness, giving the unique characteristics of various surface analyzer instruments; (2) Nature of Surface Defects Produced by Grinding and Other Machining, which constructs for the reader a germ's-eye view of such surfaces; (3) Types of Surface Damage; (4) Relation of Surface Finish to Wear, which is quite revealing; (5) The Efficient Oil Film, and its relation to or dependence on proper surface finish and geometry; (6) Selection of Proper Surface Finish, giving the fine points of bearing design and manufacturing principles; (7) The Most Efficient Method of Surface Finishing, which is a rather complete discourse on superfinishing characteristics, detailed methods, advantages, recommendations, and time required; (8) Tests of Load Capacities of Different Surface Finishes, results of which define the superiority of superfinishing; and (9) Commercial Applications, illustrating diversity of uses.

*Published by Gisholt Machine Co. Copies are available at no charge to readers who circle No. 1321 on the request card, page 32B.

**1322. Annealing Furnaces**
8-page illustrated booklet on continuous annealing furnaces. Schematic diagrams, photographs, and actual production data. *Drever*

**1323. Anodized Coatings**
Bulletin 894 on equipment for testing strength of anodized coatings on aluminum. *General Electric*

**1324. Anodizing**
Bulletin on racks for anodizing, bonderizing, electropolishing and plating. *New England Rack*

**1325. Atmosphere Furnace**
Reprint on bright annealing of copper in atmosphere furnace. *Holcroft*

**1326. Atmosphere Furnace**
Bulletin on controlled atmosphere furnace. *Industrial Heating Equipment*

**1327. Atmospheres**
Bulletin 1-10 supplies technical information on inert gas generators and data on costs. *C. M. Kemp Mfg.*

**1328. Automatic Polishing**
14-page, illustrated brochure describes automatic equipment for polishing, buffing and grinding. *Murray-Way*

**1329. Band Saws**
12-page Bulletin G52 horizontal metal cutting band saw machines. Reference chart for selection of blade, feed, speed. *Wells Mfg. Corp.*

**1330. Barrel Finishing**
Bulletin on increased efficiency, lower cost in barrel finishing. *Minn. Mining*

**1331. Barrel Finishing**
22-page book on single-unit installation to yield savings up to 95% in finishing various parts. *Almco Div.*

**1332. Barrel Plating**
Folder on barrel plating with unique contact arrangement for maximum current distribution. *Daniels*

**1333. Bending**
Catalog on presses for bending, forming, blanking, drawing and multipunching. *Cleveland Crane & Engineering*

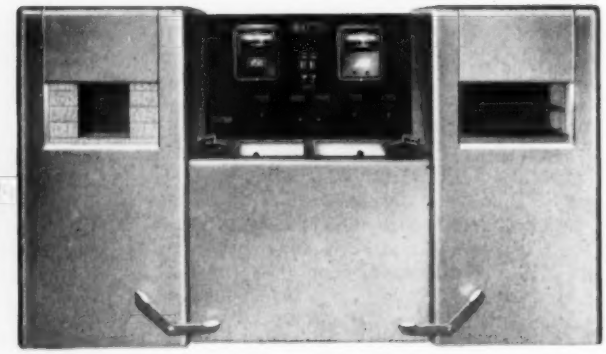
**1334. Beryllium Copper**
Helpful engineering information contained in monthly beryllium copper technical bulletins. *Beryllium Corp.*

**1335. Black Oxide Finish**
Bulletin on dip process for putting black oxide finish on ferrous metal. *Special Chemicals*

# OWN YOUR OWN HEAT-TREATING PLANT

## *low in cost high in productivity compact in design*

here it is in a single unit



Hundreds of shops are enjoying the advantages of their own heat-treating department with this new Waltz Heat-Treating Furnace. It heat-treats, quenches, draws, stress-relieves, normalizes, anneals, with controlled atmospheres. You avoid costly production tie-ups caused by waiting for expensive outside services. What a money-saver right from the start . . . what a wise investment! Mail the coupon for complete details.

**Features include:**

1. *Heating Furnace with range of 1000° to 2400° F. automatically controlled (12" wide x 10" high x 18" deep).*
2. *Tempering or Drawing Oven is recirculating type. Work is constantly bathed with evenly distributed high velocity and held to constant temperature by automatic control. Alloy steel lined with perforated shelf, has range of 250° to 1100° F. (21" wide x 10" high x 18" deep).*
3. *Furnace and Oven doors equipped with foot treadles.*
4. *Two Quench Tanks for oil and water. By means of double wall construction, oil tank is entirely surrounded by water for cooling oil, thus producing more uniform quenching.*
5. *Automatic electronic type controls.*
6. *Shipped ready to install by simply connecting gas and electric power line.*

A complete line of WALTZ standard or special heat-treating furnaces, using all types of fuels are built to suit your requirements. Write for comprehensive illustrated bulletins.

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Please send without obligation engineering bulletins—Waltz Heat-treating Furnaces.

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**Waltz furnace company**
SYMMES STREET
CINCINNATI, OHIO


**1336. Black Oxide Finish**
Folder on penetrating black finish for ferrous metal. *Puritan Mfg.*

**1337. Blackening Compounds**
Bulletin on blackening compounds (for ferrous alloys) to AMS Spec. 2485. *Swift Industrial Chemical*

**1338. Blackening Copper**
Bulletin of operating instructions for blackening and coloring copper and copper alloys. *Enthone*

**1339. Blast Cleaning**
24-page Bulletin 400 on blast cleaning installations for large work. *Pangborn*

**1340. Brass Plating**
Procedure for white brass plating. *Promat Div.*

**1341. Brazed Tubing**
12-page data book on brazed tubing made from copper-coated steel. *Bundy*

**1342. Brazing**
50-page text GEA-3193 describes the methods and applications of electric-furnace brazing. *General Electric*

**1343. Brazing and Annealing**
Bulletin on high speed heating equipment for brazing, flame annealing, flame hardening, selective heating, and heating for forming. *Gas Appliance Service*

**1344. Brazing Fluxes**
Data sheet on fluxes for copper and silver brazing. *Special Chemicals*

**1345. Bronze**
12-page bulletin on properties and uses of continuous cast bronze rod and tube. *American Smelting & Refining*

**1346. Bronze**
Folder gives tables of properties, uses, forms and other data on phosphor bronzes. *Chase Brass & Copper Co.*

**1347. Buffing and Cleaning**
24-page booklet describes origin and development of various metal cleaners and tripoli compositions. *Puritan Mfg.*

**1348. Burners**
Bulletin 123 on new series of burners for multi-purpose furnaces. *North American Mfg.*

**1349. Burners**
Bulletin on combination gas and oil burner. *Ra-Diant Products*

**1350. Burners**
16-page bulletin on selection of gas burners. *Western Products*

**1351. Carbide Segregation**
Effect of carbide segregation in tool steel. *Latrobe Steel*

**1352. Carbide Tools**
44-page Catalog 451 on carbide tools. *Willey's*

**1353. Carbides**
16-page catalog of carbide blanks, inserts and tools; 5 pages of technical data on applications. *Newcomer*

**1354. Carbides**
56-page Catalog 441 on carbide blanks and tools; 12 pages of technical data. *Vascoloy-Ramet*

**1355. Carbon and Graphite**
20-page catalog on carbon and graphite applications in metallurgical, electrical, chemical and process fields. *National Carbon*

**1356. Carbon Control**
Technical report on instrument for control of carbon potential of furnace atmospheres. *Lindberg Engineering*

**1357. Carbon Control**
Catalog T-623 describes the Microcarb control system that continuously measures the active carbon in the furnace atmosphere during heat treatment. *Leeds & Northrup*

**1358. Carbon Steel**
Data folders on four types of carbon steel castings. Composition, properties, hardenability bands, uses. *Unitcast*

**1359. Carbonitriding**
Literature on Ni-Carb (carbonitriding) treatment for surface hardening. *American Gas Furnace*

**1360. Carbonitriding**
Bulletin 241 on gas-fired radiant-tube furnace for carbonitriding and other heat treating. *Lindberg Engineering*

**1361. Casting Specifications**
Design values for five grades of heat resistant castings. *Ohio Steel Foundry*

**1362. Castings, Bronze**
16-page booklet on sand and centrifugal castings. *Amer. Non-Gran Bronze*

**1363. Chromate Coatings**
Folder gives characteristics and uses of chromate conversion coatings on nonferrous metals. *Allied Research*

**1364. Chromium Stainless**
12-page book, "Type 430 Stainless Steels as Alternates of the 18-8 Series". Fabrication data, four pages of comparative corrosion ratings for Types 430, 302 and 316. *Republic Steel*

**1365. Cleaning**
20-page book on electrolytic and nonelectrolytic cleaning, tumbling, paint stripping. *Magnuson Products*

**1366. Cleaning**
12-page bulletin on washing and drying machines; conveyor, cabinet, drum and vertical types. *Industrial Systems*

**1367. Cleaning Aluminum**
Set of seven data sheets on cleaning and finishing of aluminum. *Pennsalt*

**1368. Cleaning Stainless**
Guidebook on cleaning of stainless steel and nickel alloy equipment. *Lukens*

**1369. Cold Finished Steel**
Engineering bulletin, "New Economies in the Use of Steel Bars". *LaSalle Steel*

**1370. Cold Finished Steel**
8-page bulletin on selection, use, relative cost of cold finished carbon steel bars. *Ryerson*

**1371. Compressors**
12-page bulletin 126-A on application of turbo compressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

**1372. Continuous Forging**
12-page reprint on automatic rotary furnace applied to continuous forging system at Dodge. *Geo. J. Hagan Co.*

**1373. Controllers**
80-page Catalog 8305 on nonindicating electric, electronic and pneumatic controllers for temperature, pressure and humidity. *Minneapolis-Honeywell*

**1374. Copper Alloys**
124-page data book on wrought copper alloys. *Chase*

**1375. Copper Alloys**
40-page handbook on phosphor bronze, nickel silver, cupro nickel, beryllium copper. *Riverside Metal*

**1376. Core Oils**
Bulletin on core oils for foundry. *Swan-Finch*


# HOW HEAT
## (UP TO 2200° F)
# CAN BE STOPPED COLD

**Destructive effects of extremely high temperature can be minimized—by using Kentanium at the critical points.**

**WHAT** is Kentanium?

Chiefly titanium carbide (and small percentages of other refractory metal carbides), with nickel "binder". Uses neither tungsten nor cobalt. Hardness: Up to 93 RA. Weight: ⅔ that of steel.

**WHAT** can it do?

Resist thermal shock, withstand oxidation and abrasion, retain great strength at high temperatures (1800°F and above).

**WHERE** is it in use?

Successful applications include: Valves, valve seats, reduction crucibles, anvils for spot welding, hot extrusion die inserts, bushings, thermocouple protection tubes, flame tubes, furnace tong tips, balls for hot hardness testing, nozzle vanes and blades for jet engines, and many others.

**WHAT** forms are made?

Tubes, rods, bars, flats by extrusion process. More complex parts by machining from pressed slugs before sintering, extremely accurate parts by grinding to required tolerance after furnace sintering.

**HOW** can you use it?

This remarkable new metal, available in many "grades" to meet specific combinations of imposed conditions, can best be adapted to your high temperature problem by cooperative effort. Our engineers will be glad to discuss how you can get best results from Kentanium.

An Exclusive Development of KENNAMETAL® Inc., Latrobe, Pa.

# KENTANIUM

HEAT-RESISTANT, HIGH-STRENGTH, LIGHTWEIGHT CEMENTED TITANIUM CARBIDE

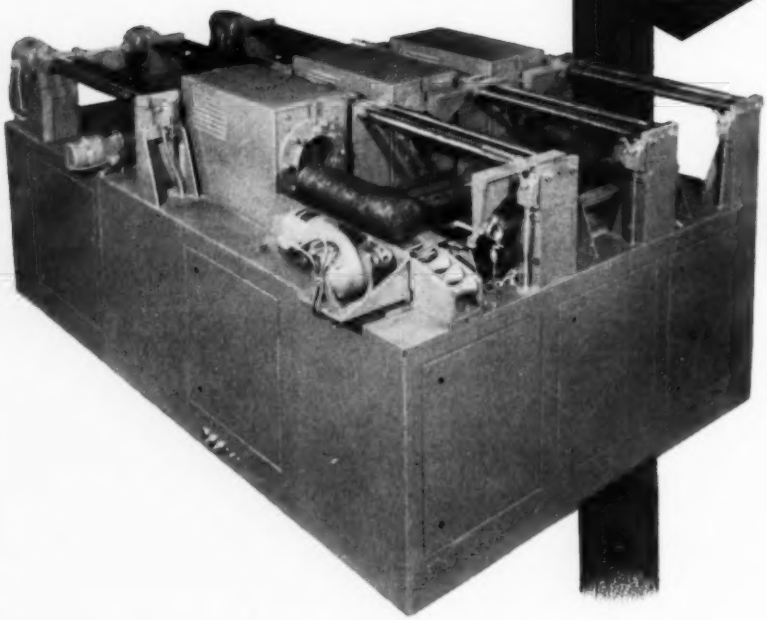
the first completely universal....

60-cycle **induction**

# BILLET HEATER

THIS Loftus Universal Thermo-Induction furnace is the most flexible 60-cycle billet heater ever designed. You can heat every non-ferrous metal, in the same furnace, either consecutively or simultaneously, to its respective forging or extrusion temperature. The unit maintains high efficiency, constantly, even when heating **short-length** billets.

Loftus Thermo-Induction gives you the most practical, dependable, and efficient method of heating non-ferrous metals. You achieve uniform heating in a matter of seconds. Production is continuous, and completely automatic. The press operator controls the furnace. Separate, positive control of each coil is at his fingertips.



The Loftus 60-cycle Thermo-Induction Heater illustrated is designed to heat copper, brass, aluminum, and cupro-nickel for extrusion purposes. The unit is readily adaptable for forging and rolling processes. It is possible, with this billet heater to heat a 5" dia. Aluminum billet to 800° F., an 8" dia. brass billet to 1550° F., and a 10" dia. cupro-nickel billet to 1950° ALL AT THE SAME TIME, IN THE ONE FURNACE. Each billet is heated independently . . . from a single control panel.

*Send Today* for Booklet describing Loftus 60 Cycle Induction Heating in Detail

Loftus **ENGINEERING CORPORATION**

Designers and Builders of Industrial Furnaces

**610 Smithfield Street • Pittsburgh 22, Pennsylvania**

**1377. Corrosion Resistance**
32-page brochure on causes of corrosion and means of combating them. Choice of materials for condenser tubes. *Revere Copper & Brass*

**1378. Corrosion Resistance**
20-page bulletin on copper alloys for corrosion resistance. Table gives applicability in 150 media. *Ampco*

**1379. Cut-Off Machinery**
Brochure on high-speed cutting machinery and wheels. *Stone Machinery*

**1380. Cut-Off Wheels**
Folder gives data, operating suggestions and grade recommendations of cut-off wheels. *Manhattan Rubber Div.*

**1381. Cutting Compounds**
Data on cutting compounds for stainless and titanium. *Hangsterfer's Labs.*

**1382. Cutting Fluids**
16-page booklet on selection of cutting fluids, testing procedures, machinability. *Pure Oil*

**1383. Cutting Oil**
New pamphlet on sulphurized oil applicable to stainless steel and more easily machined alloys. *Gulf Oil*

**1384. Cutting Oil**
Facts on more efficient and economical plant operation through use of right lubricants described in "Metal Cutting Fluids" booklet. *Cities Service*

**1385. Cutting Oil**
Shop notebook gives important facts on right cutting fluid for any machining operation. *D. A. Stuart*

**1386. Cutting Oil Chart**
Selection chart for seven classes of metal in nine machining operations. *Aldridge Industrial Oils*

**1387. Definitions**
36-page glossary of over 150 terms on cast iron. *International Nickel*

**1388. Degassing Copper Alloys**
Bulletin on use of copper oxide to prevent formation of hydrogen gas in copper alloy castings. Comparison of six methods to maintain oxidizing conditions during melting. *Glidden Co.*

**1389. Degreasing**
Bulletin on aromatic type of safety degreaser. *Curran*

**1390. Degreasing**
Pamphlet on properties and use of trichlorethylene. *Niagara Alkali*

**1391. Descaling Process**
8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. *Du Pont*

**1392. Descaling Stainless Steel**
Bulletin 25 on descaling stainless steel and other metals in molten salt. *Hooker Electrochemical*

**1393. Die Casting Machines**
Bulletin on 1-lb. capacity die casting machines for zinc and aluminum. *DCMT Sales*

**1394. Die Casting Machines**
Copies of "Lester Press" describe various features of aluminum die casting machines. *Lester-Phoenix, Inc.*

**1395. Die Casting Machines**
22-page catalog shows complete line of die casting machines. *Kux Machine*

**1396. Electric Furnaces**
Bulletin 473 on automatic melting machine for ferrous and nonferrous alloys. *Detroit Electric Furnace*

**1397. Electroforming**
Bulletin on production of intricate parts and precision components by the electroforming process. *Bart Labs.*

**1398. Electron Microscope**
New 20-page brochure describes in detail ten case histories in which the electron microscope has been at work solving problems of development and control in industrial laboratories. *RCA*

**1399. Expanded Metal**
28-page book on uses of expanded metal. Stainless steel, aluminum, Monel, Inconel, carbon steel. *Penn Metal*

**1400. Fans**
16-page Bulletin 6001 on fans for exhaust hoods, recirculating cold air in subzero freezers and other applications. Detailed tabular data on performance. *Robinson Ventilating*

**1401. Temperature Control**
This 24-page manual defines the different types of control systems and distinguishes between them so that the engineer can select the type best suited

to a particular application. Some of the concepts discussed are: the control circuit versus the load circuit; one-point, two-point and program control; two-wire, three-wire and potentiometric control; two-position control; the use of diaphragm valves; and the reasons for three different types of temperature-sensitive elements being available. *Partlow Corp.*

**1402. Fasteners**
Slide calculator gives threads per inch, tap drill size, body drill and counterbore sizes for different screw diameters. Decimal equivalents of all drill sizes from No. 80 to 1 in. *Standard Pressed Steel*

**1403. Fasteners**
20-page catalog and reference book on set screws. *Set Screw & Mfg. Co.*

**1404. Fasteners**
20-page data book for designers and engineers. Selection and applications of one-piece blind rivets with threads. Engineering and assembly data. *B. F. Goodrich*

**1405. Fasteners**
40-page Engineering Folder S-49 on screw or bolt and washer assemblies. *Reliance Div., Eaton Mfg.*

**1406. Fasteners**
24-page brochure is a guide to selection. Descriptions are given of 36 representative types of locknuts made by 21 manufacturers. *Ind. Fasteners Inst.*

**1407. Fastening Specialties**
22-page Catalog B2 on screw fasteners, blind rivets, adjustable pawl fasteners, spring-grip fasteners, anchor nuts and other specialties. *Southco*

**1408. Ferro-Alloys**
64-page book describes over 50 metals and alloys produced by the company. *Electro Metallurgical*

**1409. Finishing**
16-page bulletin on phosphatizing machine and other finishing equipment. *Cincinnati Cleaning & Finishing Mach.*

**1410. Finishing**
Book, "Abrasive Grain and Powders for Use in Metal Finishing". *Abrasives Div., Carborundum*

**1411. Finishing Aluminum**
Brochure "How To Cut Die-Casting Finishing Costs" deals with aluminum castings. *Monarch Aluminum*

**1412. Finishing Systems**
Bulletin on cleaning and rust-proofing equipment, spray booths and drying ovens. *Peters-Dalton*

**1413. Flaw Detection**
12-page bulletin on location of flaws by two dye-penetrant inspection methods. *Turco Products*

**1414. Flaw Detection**
Reprint describes penetrant dye method for detecting fine surface defects. *Met-L-Chek Co.*

**1415. Flaw Detection**
Illustrated bulletin on Spotcheck, new dye-penetrant method for locating surface defects. *Magnaflux*

**1416. Flow Meters**
Bulletin on gas flow meter for furnace installations. *Hays Corp.*

**1417. Flow Meters**
12-page Bulletin 2M50 on mechanical flow meters that give high accuracy at low flows. *Hagan Corp.*

**1418. Flow Meters**
Bulletin 201 on flow meter for gas used in heat treating. *Waukee Engineering*

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Data sheet on four fluxes for degassing and purifying aluminum alloys. *Atlantic Chemicals & Metals*

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Folder on manipulators for automotive, ordnance, aluminum and specialty forging. *Salem-Brosius*

**1421. Forgings**
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**1423. Forming**
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**1424. Forming Dies**
Data on roller dies for forming tubes and rolled shapes. *American Roller Die*

**1425. Foundry**
Bulletin F-1 on properties and use of water-dispersing resin sand binder. *Reichhold Chemicals*

**1426. Foundry Practice**
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**1427. Free-Machining Steel**
8-page booklet on new free-machining cold finished steel. Eight case histories. *Jones & Laughlin*

**1428. Furnace**
Bulletin 294 on ingot heating pit furnace. Performance data, drawings, amortization chart. *Amsler Morton*

**1429. Furnace Belts**
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Bulletin on instruments and controls for heat treating furnaces. *Hays Corp.*

**1431. Furnace Fixtures**
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**1432. Furnace Fixtures**
Bulletin 111 on cast Ni-Cr fixtures for gas carburizing. *Fahralloy*

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**1435. Furnaces**
12-page Catalog I-2 on method of atmospheric control for hardening high speed steel. *The Sentry Co.*

**1436. Furnaces**
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**1437. Furnaces**
Bulletin HT-53 on furnaces for heat treating, other applications. *Carl-Mayer*

**1438. Furnaces**
16-page bulletin on gas, electric and oil furnaces for heat treating and melting. *Knapp*

**1439. Furnaces, Heat Treating**
Bulletin on fuel and electric furnaces for heat treating. *Dempsey*

**1440. Furnaces, Heat Treating**
Catalog on furnaces for tool room and general-purpose heat treat. *Cooley*

**1441. Furnaces, Heat Treating**
32-page catalog on high-speed gas furnaces for heat treating carbon and alloy steels; also pot furnaces for salt and lead hardening. *Charles A. Hones*

**1442. Furnaces, Heat Treating**
Bulletin on furnaces for annealing, normalizing, hardening, tempering, forging. *Flinn & Dreffein Engineering*

**1443. Furnaces, Heat Treating**
12-page bulletin on conveyor furnace, radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*

**1444. Furnaces, Laboratory**
26-page "Construction of Laboratory Furnaces" contains many diagrams, charts, tables, and information on how to construct furnaces. *Norton Co.*

**1445. Furnaces, Small Tool**
Folder describes complete set-up for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

**1446. Gas Analysis**
60-page book on theory of gas analysis, procedures, maintenance and operation of equipment. *Fisher Scientific*

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**1454. Hardness Tester**
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**1463. Heat Treating Ammonia**
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**1466. Heat Treating Fixtures**
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**1473. High-Temperature Belts**
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**1475. High-Tensile Steel**
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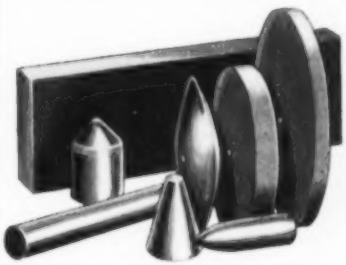

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**1562. Salt Bath Furnaces**
Information on electrode-type salt bath furnaces. *Bellis*

*(Continued on p. 32A)*

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- dissociated ammonia
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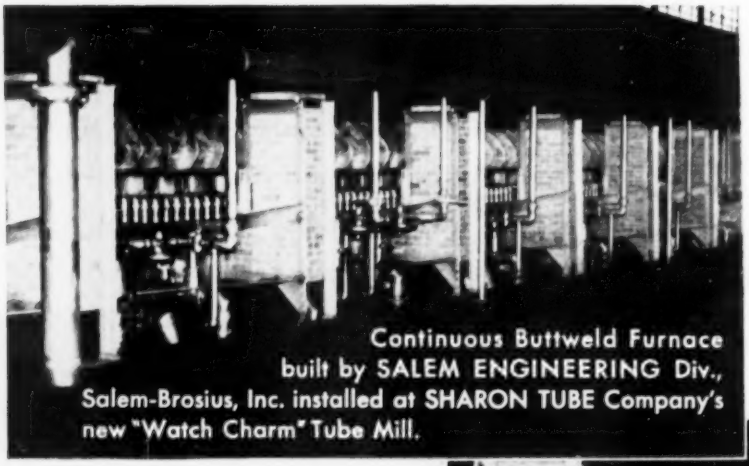

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**187**
**lb/hr per sq ft of hearth**

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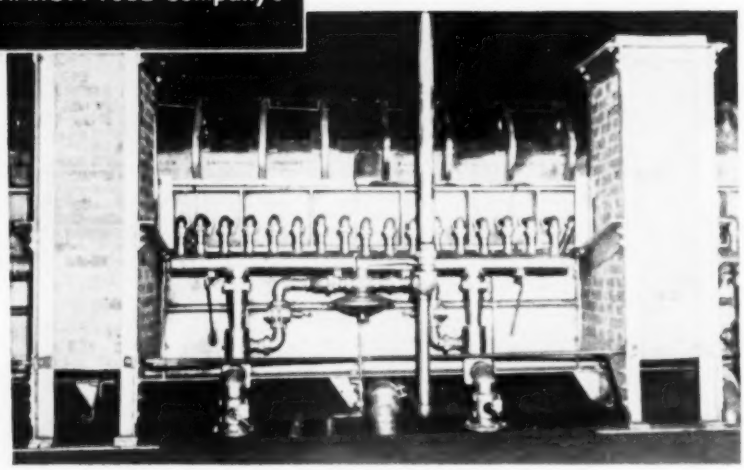

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*(Continued from p. 30)*

**1563. Salt Baths**
Bulletin H-1 on neutral salt baths and their operation. *Park Chemical*

**1564. Salt Baths**
32-page bulletin on salts for tempering, annealing, neutral hardening, martempering and carburizing. Heat treating data. *E. F. Houghton*

**1565. Screw Thread Inserts**
Design Handbook 652 on screw thread bushings for all metals. *Heli-Coil*

**1566. Selective Carburizer**
Information on new product for use as stop-off during selective carburizing. *Walmil Co.*

**1567. Silicone-Base Finish**
New brochure on silicone-base heat-resistant finish. *Midland Ind. Finishes*

**1568. Silver Brazing**
Series of eight technical bulletins on silver brazing. Joint strength, design, stress analysis, heat treatment, fluxes. *Handy & Harman*

**1569. Silver Brazing**
10-page technical bulletin on brazing preforms. Specifications for 13 types of joints. *Lucas-Milhaupt*

**1570. Sheet Metal Testing**
8-page folder on equipment for testing the drawing, stamping and folding qualities of sheet and strip. *Deakin*

**1571. Sheet Separation**
Data on magnetic device for automatic separation of stacked steel sheets. *Basco Mfg.*

**1572. Shell Molding**
8-page technical bulletin on shell molding process for stainless steel. *Cooper Alloy Foundry*

**1573. Shot and Grit**
Handy calculator has size data for SAE grades of shot and grit. *Pangborn*

**1574. Shot Peening**
Selection and use of shot and grit for peening. *Cleveland Metal Abrasive*

**1575. Silicon Bronze**
Article on silicon bronze from "Lavingot Technical Journal". *Lavin*

**1576. Slitting**
76-page book on slitting lines for coils and sheets. Design, selection, operation, time studies of operating cycle. *Yoder*

**1577. Sodium**
24-page book on handling sodium in the laboratory and plant. Application to descaling. *Ethyl Corp.*

**1578. Soldering**
Bulletin on solder preforms for various methods. *Kester*

**1579. Soldering Aluminum**
Article on techniques and materials for soldering aluminum. *Reynolds Metals*

**1580. Solution Heating**
Bulletin 12 on electric heating of pickling and plating solutions. *Pyrosil*

**1581. Sonic Thickness Tester**
Measurement of wall thickness from one side by sonic method. *Branson*

**1582. Specification Key**
Guide to Government specifications for phosphatizing, rust-proofing and paint bonding chemicals. *American Chemical Paint*

**1583. Spectrophotometer**
Bulletin B-211 on junior-size spectrophotometer for identifying and measuring solution constituents. *Harshaw*

**1584. Spray Painting**
16-page bulletin on electrostatic process for spray painting. Seven case histories. *Ransburg Electro-Coating*

**1585. Spring Steels**
Spring steel catalog offers 785 sizes of hardened and tempered spring steels, and 133 cold-rolled and bright annealed sizes in stock. *Sandvik Steel*

**1586. Spring Testing**
Bulletin 2403 on machines for testing torsion springs. *Testing Equipment Co.*

**1587. Stainless Fasteners**
Slide-chart selector, in terms of AN specification numbers, gives data for nuts, screws, rivets, cotter pins, washers, all of stainless steel. *Anti-Corrosive Metal Products Co.*

**1588. Stainless Steel**
Bulletin gives examples of five types of stainless steel castings. *Sivyer*

**1589. Stainless Steel**
Bulletin shows plates, forgings, sheets, tank heads, flanges. *G. O. Carlson*

**1590. Stainless Tubing**
28-page book on corrosion, fabrication of stainless steel *Steel and Tubes Div., Republic*

**1591. Stainless Tubing**
Data Card 153 gives stress data for nine grades of stainle *cock & Wilcox*

**1592. Steel 52100**
Data sheet on high-purity 52 vacuum melted. *Vacuum Met*

**1593. Steel 52100**
New stock list on 52100 tub and ring forgings. *Peterson S*

**1594. Steel Plate**
32-page catalog 1243 on steel carburizing, heat treating and Many uses illustrated. *W. J. F*

**1595. Steel Specification**
Chart identifies 60 Militar Navy, Aeronautical and Fed specifications, with nearest co ing SAE, AISI, AMS number

**1596. Steel Tubing**
May issue of Tube Bulletin article on improvement of c tubular products. Also detai list. *A. B. Murray*

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Bulletin 52-AA describes st ing machine for wire in size ra 1/16 to 1 in. diameter, at spe 200 ft. per min. *Medart Co.*

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8-page folder on portable 110-volt a.c., operating to —1 shrink fitting, hardening, s and testing. *Webber Appliance*

**1599. Subzero Freezer**
Data on chest for use down t for production use and testin

**1600. Subzero Tests**
62-page bulletin on equip low-temperature tests. *Bow nical Refrigeration*

**1601. Surface Pyrometer**
Bulletin 168 on instrument accurate readings of surface tures. *Pyrometer Instrument*

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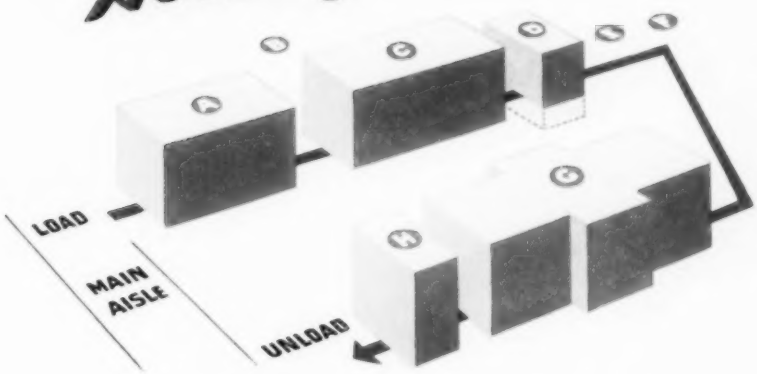


- Ⓐ Direct gas-fired normalizing furnace
- Ⓑ Controlled cooling zone
- Ⓒ Direct gas-fired hardening furnace
- Ⓓ Quench tank and elevator for oil or water
- Ⓔ Drain section
- Ⓕ Transfer (and tip over) from drain section to draw furnace
- Ⓖ Indirect gas-fired draw furnace
- Ⓗ Tip-over at discharge end of draw furnace

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**A new furnace layout—designed to bat for five existing furnaces—handles overflow production, replaces any furnace down for repairs, and has the extra capacity for treating war-production forgings of special alloy steels.**

**Designed by Holcroft, the unit as laid out above, is the buffer behind existing furnaces which normalize, anneal, harden-quench-draw, normalize-harden-quench-draw, or cycle anneal the forging production. A "U-type" layout puts both charge and discharge ends of the unit on a main trucking aisle to simplify material routing.**

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**1603. Tanks and Linings**
16 pages of data on tanks and corrosion-resistant linings for cleaning and plating solutions. *Chemical Corp.*

**1604. Temperature Control**
Catalog of pyrometer supplies gives data on thermocouples, protection tubes, other accessories. *Arklay S. Richards*

**1605. Temperature Control**
Data sheets on high resistance indicating pyrometers. Also controls and resistance thermometers. *West Instr.*

**1606. Temperature Control**
36-page bulletin P 1245 on new electronic instruments for recording and indicating variables. *Bristol Co.*

**1607. Tempering**
Bulletin 1E 11 on tempering and other applications in liquid baths. *Kemp*

**1608. Tempering**
Reprint of article on controlled atmosphere tempering. *Ipsen*

**1609. Tempilstiks**
"Basic Guide to Ferrous Metallurgy", a plastic laminated wall chart in color. *Claud S. Gordon*

**1610. Test Chambers**
Bulletin on test chambers for temperatures from −100 to +200° F., humidity from 20 to 90%, pressures corresponding to 0 to 80,000 ft. altitude. *Tenny Eng.*

**1611. Testing**
Bulletin 47 on Super L universal testing machines. *Tinius Olsen*

**1612. Testing**
Booklet on Reflectoscope tells how ultrasonic vibrations penetrate up to 24 feet to "see" internal defects and fatigue cracks. *Sperry Products*

**1613. Testing Machines**
32-page catalog on hydraulic testing machines. 10 models described; also accessories. *Riehle*

**1614. Testing Springs**
Bulletin on two high-power spring-testing machines. *Testing Equipment*

**1615. Testing Tubing**
Bulletin on test stand for determining physical characteristics of tubing up to 3 in. dia. *Dommers Co.*

**1616. Textured Stainless**
Folder on stainless to conserve alloys and reduce weight. *Rigidized Metals*

**1617. Thermocouple Data**
42-page Bulletin TC-9 on thermocouples, radiation detectors, resistance bulbs, accessories. *Wheelco*

**1618. Thermocouple Sheath**
Bulletin 6169 on graphite thermocouple sheath parts. *National Carbon*

**1619. Thermocouples**
20-page Bulletin 714 on thermocouples, protecting tubes and wells, insulators, leads, connectors, heads. *Gen. Electric*

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**1621. Tool Steel**
Comprehensive data book on drill rod. *Solar Steel*

**1622. Tool Steel Selector**
Twist the dial of the 9-in. circular selector and read off the tool steel for your application. *Crucible Steel*

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Catalog describes two-roll rotary straightener for round tubes and bars 1/16 to 3/16 in. O.D. *Medart Co.*

**1624. Tubing**
12-page Bulletin 103 on stainless, alloy and carbon steel tubes, seamless and welded. *Globe Steel Tubes*

**1625. Tubing**
52-page "Handbook of Seamless Steel Tubing". 26 pages of data. *Timken*

**1626. Tubing Handbook**
Handbook E-4 on resistance welded steel tubing. *Ohio Seamless Tube*

**1627. Tumbling Barrels**
10-page catalog B-8 gives specifications, applications of six types of tumbling barrels. *Globe Stamping Div.*

**1628. Uranium**
36-page book on uranium industry of the Colorado Plateau. *U. S. Vanadium*

**1629. Vacuum Calculator**
Slide rule for quick calculation of data necessary in vacuum engineering and processing—for instance, pump capacities and time to reach given vacuum. Pertinent conversion tables on back. *F. J. Stokes Machine*

**1630. Vacuum Metallizing**
Bulletin on equipment for industrial vacuum metallizing. *Optical Film Eng.*

**1631. Vacuum Metallurgy**
Bulletin gives résumé of vacuum metallurgical operations and research and development facilities and services available. *National Research Corp.*

**1632. Weld Positioners**
Bulletin R-228A on turning rolls for positioning cylindrical forms for welding. *Worthington Corp.*

**1633. Welding Electrodes**
Application chart for stainless, alloy and nonferrous electrodes. *Weldwire*

**1634. Welding Electrodes**
Bulletin on electrode selection for welding stainless and alloy steels. *Arcos*

**1635. Welding Equipment**
Catalog on Cadweld process and arc-welding accessories. *Erico Products*

**1636. Welding Steel**
12-page booklet guides users of low-alloy, low-hydrogen electrodes. *Arcos*

**1637. Welding Magnesium**
Article on inert-gas-shielded metal-arc welding of magnesium includes numerous illustrations and tables of data. *Dow Chemical*

**1638. Weld-Rod Dehydrating**
Bulletin on low-hydrogen electrode stabilizer. Specifications of equipment for dehydrating mineral shielding on low-hydrogen electrodes. *Archer*

**1639. Wire Mesh Belts**
140-page manual on conveyor design, belt specifications, metallurgical data. *Cambridge Wire Cloth*

**1640. X-Ray Diffraction**
Analytical applications of X-ray diffraction using direct measurement techniques. *X-Ray Dept., General Electric*

**1641. X-Ray Inspection**
248-page catalog and supplement on materials used in X-ray inspection. *Picker X-Ray*

**1642. X-Ray Supplies**
50-page catalog of industrial X-ray supplies and accessories. *Westinghouse*

**1643. Zircon Ware**
20-page bulletin on zircon refractory ware for laboratory use. *Laboratory Equipment Corp.*

May, 1953

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Here are some of the places where "National" carbon and graphite can follow up their good work in the furnace...improve production, deflate maintenance cost, increase product quality and better the safety of equipment and personnel.

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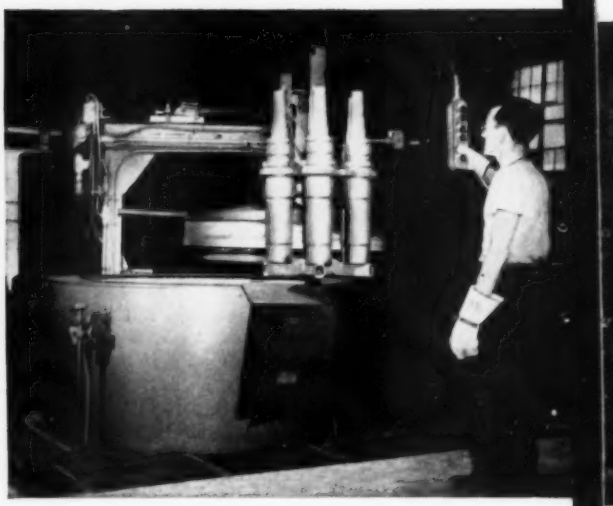
# 4 REPORTS ON MICROCARB® CONTROL... FROM PRODUCTION HEAT TREATS



## 1 TOLERANCES HELD

● This row of L&N furnaces is in the Heat Treating Department of Jones and Lamson, Springfield, Vt., manufacturers of turret and automatic lathes, thread grinders, comparators, dies and chasers. In the foreground is a Homocarb furnace with Microcarb Control—panels are against the wall at the right.

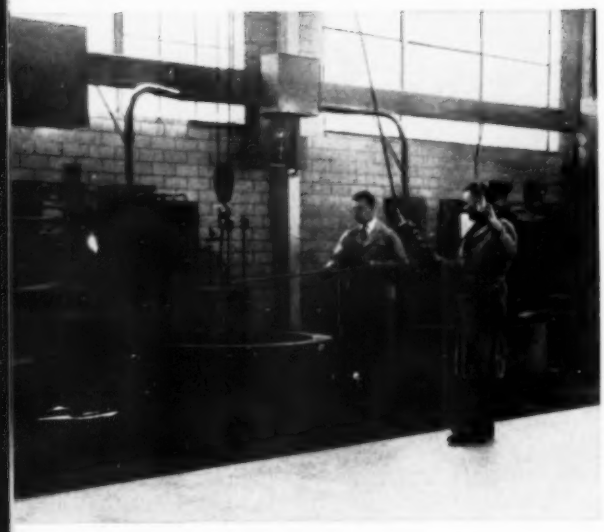
The part being removed is a work slide bar for a J&L Model D Vertical Slide Form Grinder. The bar is made from 5% chrome, 1% carbon air hardening steel. Specifications are 64 plus, in Rockwell C uniform surface hardness. These bars are ground to a ± .0002 inch tolerance on outside dimensions and zero on straightness and eccentricity and must remain stable. Control of surface carbon chemistry and distortion during heat treatment are extremely important.

● At right is an adjusting cone for the spring collet on a J&L Bar Type Turret Lathe. These cones are 8″ in diameter by 5″ deep with $\frac{3}{8}$″ walls, and are made from 5% chrome, 0.10% carbon air hardening carburizing steel. While machining and physical characteristics of this steel are excellent, it requires precise control of furnace atmosphere during carburizing to meet J&L's requirements for uniform surface hardness of 60 to 63 Rockwell C. J&L carburize these parts at 1750 F with Microcarb atmosphere control—air cool then stress relieve them in an L&N Homo Tempering furnace at 300 F. They report not only that they have no difficulty meeting specifications on individual loads, but can reproduce the same cycle time after time.

## 2 DISTORTION NEGLIGIBLE

● Taft-Peirce in Woonsocket, R. I. installed their Homocarb® furnace with Microcarb Control to improve physical characteristics . . . particularly by maintaining surface carbon content during hardening of these aircraft "prop" shafts made of AMS 6415 steel. Each shaft measures 6 inches in diameter by 30 inches long and weighs 125 pounds.

Six shafts are run at once . . . loads are brought to 1550 F and held for 4 hours with a carbon setting of 0.45%... then oil quenched. The firm reports that specifications—for strength, elongation, reduction in area, etc.—are held without difficulty on every load; work comes out clean and distortion is negligible.



## 3 FINISHING REDUCED

● Just in front of the control panels is the 15″ x 18″ Homocarb furnace with Microcarb Control in which the W. H. Nichols Company, Waltham, Mass., heat treat aircraft gears like the one above. The gears, measuring $3\frac{1}{2}$ inches in diameter, are made of AMS 6260 and 6274 nickel-chromium-molybdenum steel. Prescribed specifications call for a minimum 81 Rockwell "A" hardness, with a .025 to .040 case free of carbide network. The operator simply sets temperature control to 1650 F and carbon control to 0.90.

Nichols also uses this furnace to harden AISI 4140 steel pump shafts. The precise L&N control eliminates undesirable decarburizing or carburizing and substantially reduces successive finishing operations that were formerly necessary.

## 4 OPERATION AUTOMATIC

● These Homocarb furnaces with Microcarb Control are used for production-line carburizing and heat treating of Universal Joint spiders made by Warner Machine Products Inc. Twenty-four of the large spiders are loaded at a time. Material is SAE-8720 steel. The load is held at 1700 F to obtain a 0.090 inch case depth with the atmosphere controlled at 0.90% to 0.95% carbon. Parts are cooled in the furnace to about 1525 F then direct oil quenched. Warner obtains a hardness of about 63 Rockwell C.

Although none of the operating personnel in this Warner Machine Plant had ever had any experience in carburizing and heat treating prior to this installation, control is so automatic that some 800,000 pounds of work were run through Warner's four furnaces in the first few months without a single loss due to heat treatment.

## WHAT MICROCARB CONTROL CAN DO FOR YOU

**With Microcarb Control you get:**

- ***Uniform Controlled Atmosphere and Temperature***
- ***Continuous Records of Carbon and Temperature***

**This means that:**

**Heat Treat Superintendents** can accurately reproduce any heat treating cycle to exact specifications.

**Works Managers** can increase production per square foot of floor space.

**Metallurgists** can specify and get any cycle within a carbon range of 0.15 to 1.15 and a temperature range of 1500 to 1750 F.

**Production Superintendents** can maintain a high continuous rate of quality production.

**Management** has proof of the quality of their product.

*The Homocarb Method with Microcarb Control is available to help you solve your heat treating problems as it is now doing in nearly a hundred plants. For more information just write us at 4927 Stenton Avenue, Phila. 44, Penna.*

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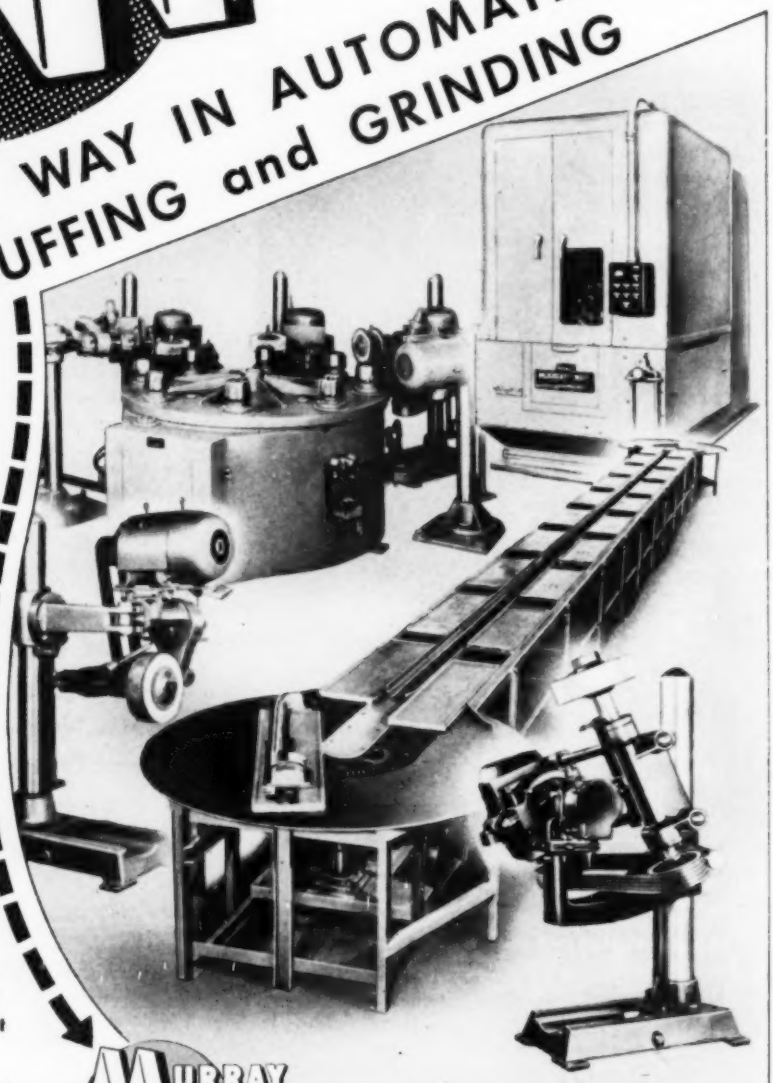
## THE *BETTER* WAY IN AUTOMATIC POLISHING, BUFFING and GRINDING



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**MICRO-POLISH**—prefinishes steel sheet, strip or blanks before forming. Gives you better plating or organic finish, easier deep draw, less die wear.

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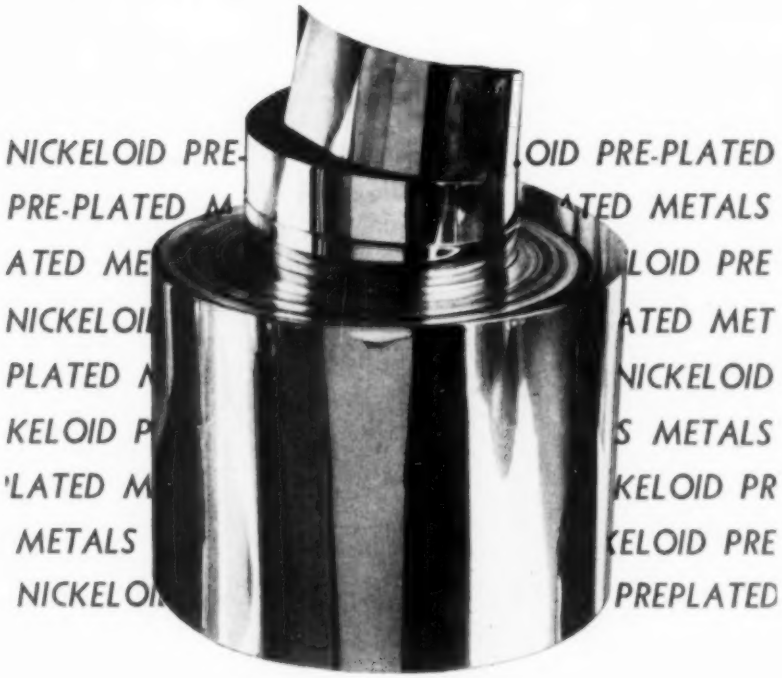


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Electro-plated TO ALL COMMON Base METALS
ALSO LACQUERED COLORS
SHEETS AND COILS
OLDEST AND LARGEST PRODUCERS OF PRE-PLATED METALS

***A Nickeloid sales engineer will be glad to call and give you more information about these modern metals and to provide working samples.***

**AMERICAN NICKELOID COMPANY**

*Established 1898*

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Do you make metal products? Maybe bird cages or flashlights? Easy to use . . . economical Nickeloid Metals add sparkling beauty to good product design, whether these metals are used in part or on the whole of your finished item. Here's a partial listing of products using Nickeloid Metals:

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|---|---|
| Bird Cages | Canister Sets |
| Door Chimes | Flour Sifters |
| Serving Trays | Bathroom Scales |
| Waste Baskets | Wax Paper Dispensers |
| Step-On Cans | Bread Boxes |

**STOVES AND HEATERS**

| | |
|---|---|
| Louvres | Stove Pipe |
| Space Heaters | Hearth Plates |
| Splash Back Panels | Door Handles |
| Broiler Grids | Stove Pads |
| Instrument Panels | Control Knobs |

**LIGHTING FIXTURES**

| | |
|---|---|
| Ceiling Lamps | Pin-Up Lamps |
| Fluorescent Fixtures | Mirror Side Lights |
| Lamp Shades | Ozone Lamps |
| Light Reflectors | Recessed Lights |

**POINT OF SALE DISPLAYS**

| | |
|---|---|
| Neon Signs | Cut-Out Letters |
| Counter Displays | Menu Signs |
| Name Brand Signs | Merchandise Racks |

**MANY OTHER PRODUCTS**

| | |
|---|---|
| Nameplates | Switch Plates |
| Napkin Dispensers | Moulding & Trim |
| Loose Leaf Devices | Metal Specialties |
| Auto Accessories | Brush Ferrules |
| Flashlights | Badges & Tags |
| Juke Boxes | Toys & Games |
| Pencil Sharpeners | Stampings |

Why *Brass* can better serve your needs

*Resistance to* CORROSION

**Brass Castings Retard the Destructive Forces of Nature**

SHIPBUILDERS require strong . . . ductile . . . corrosion resistant metal for propellers.

IN INDUSTRY brass is selected to convey corrosive liquids.

AT HOME or wherever liquids are used . . . Brass plays a necessary role.

FREE . . . Write for your copy of the 8-page "Lavinyot Technical Journal — Vol. 9, No. 1 — containing an article discussing Silicon Bronze

*Specify*—LAVIN NONFERROUS INGOT—*Quality*

Brass · Aluminum · Bronze · Zinc Base Die Casting Alloys

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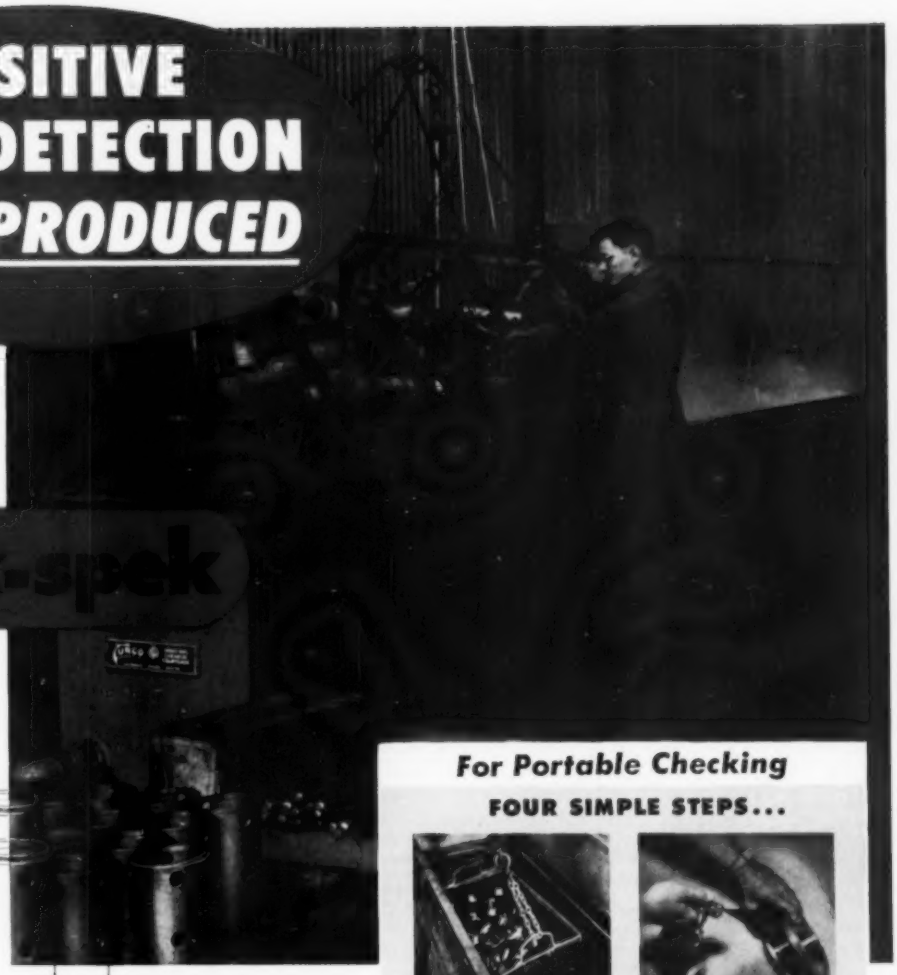
REPRESENTATIVES IN PRINCIPAL CITIES

R. LAVIN & SONS INC. 1900 *53 Years* 1953 SERVING THE FOUNDRY INDUSTRY

# POSITIVE FLAW DETECTION *MASS PRODUCED*



*with* TURCO chek-spek

**ACCURATE . . . SIMPLE . . . FAST . . . ECONOMICAL**

. . . and now . . . *for small parts* . . . through Turco Chek-Spek . . . you get positive flaw detection . . . *on a production line schedule.*

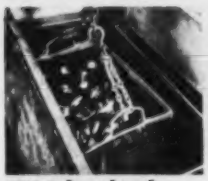
Basically, Turco Chek-Spek employs the dye-penetrant method made famous on large units by Turco Dy-Chek. Here, for the first time Turco brings you a medium, Chek-Spek, which will accurately inspect thousands of parts per hour. If you are interested in cutting costs and improving quality, get the Turco Chek-Spek *mass production* story today.

## *For Portable Checking*

**FOUR SIMPLE STEPS...**

**STEP 1:** Clean surface

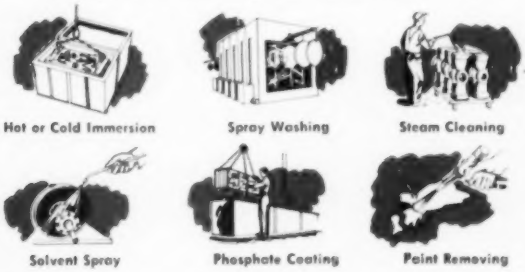
**STEP 2:** Apply Dy-Chek Dye Penetrant



**STEP 3:** Remove Excess Dye Penetrant with Dy-Chek Dye Remover

**STEP 4:** Apply Dy-Chek Developer. Flaws are revealed

**For Cleaning or Metal Conditioning Problems...Turn to Turco First!**




**67 SPECIALIZED SERVICE CENTERS**

From coast-to-coast and border-to-border Turco specialists and Turco warehouses are in most principal cities. Consult your local classified phone book for the one nearest you.

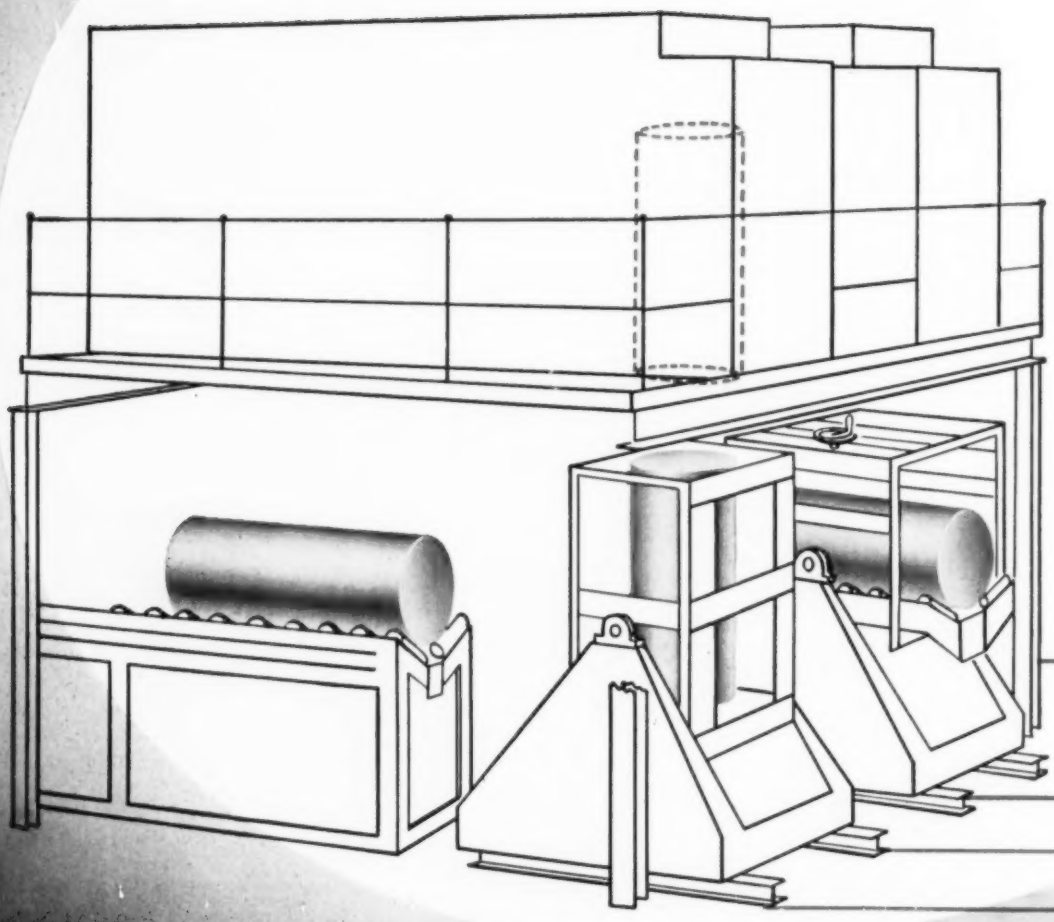
**TURCO PRODUCTS, INC.**

**Chemical Processing Compounds**

6135 South Central Ave., Los Angeles 1

Factories:
Newark, Chicago, Houston, Los Angeles

# Big press program goes



MAGNETHERMIC
corporation
3990 SIMON ROAD YOUNGSTOWN 7, OHIO
INDUCTION HEATING

# MAGNETHERMIC

## SUPER-PRESSES

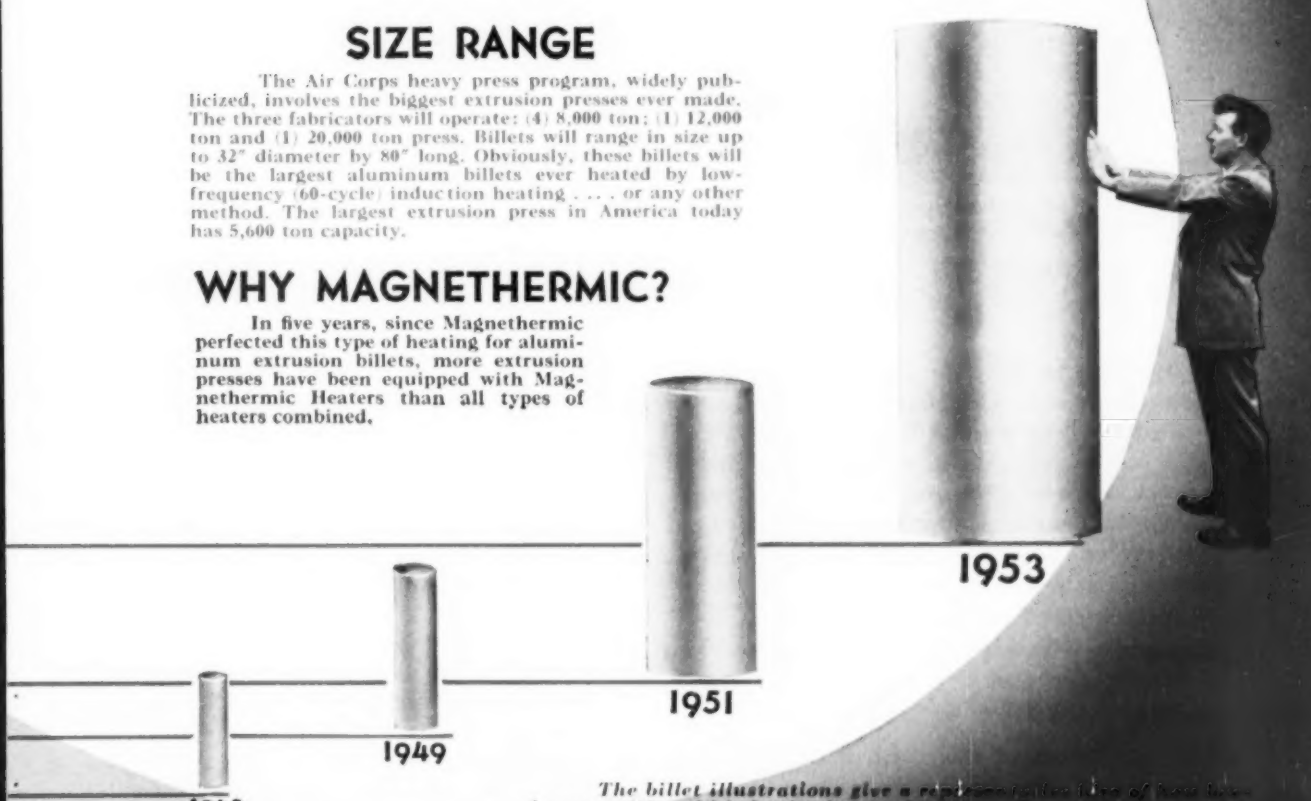
**The super-size aluminum billets for the Air Corps presses will be heated by low-frequency (60-cycle) induction heating perfected by Magnethermic. Three of the large aluminum fabricators active in the heavy press program have placed orders for Magnethermic Heaters. Development of the heaters for the goliath presses started in Magnethermic's laboratories many months ago. To expedite the Air Corps units, along with regular domestic business, the company is expanding manufacturing facilities.**

## SIZE RANGE

The Air Corps heavy press program, widely publicized, involves the biggest extrusion presses ever made. The three fabricators will operate: (4) 8,000 ton; (1) 12,000 ton and (1) 20,000 ton press. Billets will range in size up to 32" diameter by 80" long. Obviously, these billets will be the largest aluminum billets ever heated by low-frequency (60-cycle) induction heating . . . . or any other method. The largest extrusion press in America today has 5,600 ton capacity.

## WHY MAGNETHERMIC?

**In five years, since Magnethermic perfected this type of heating for aluminum extrusion billets, more extrusion presses have been equipped with Magnethermic Heaters than all types of heaters combined.**

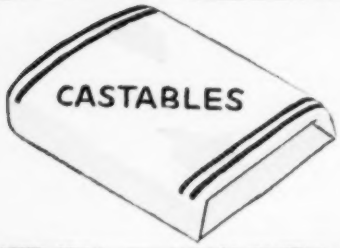


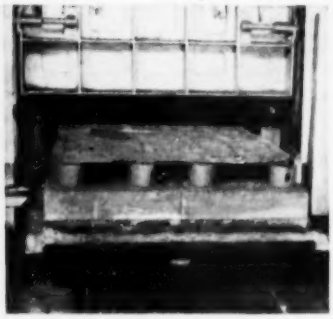

*The billet illustrations give a representative idea of how low-frequency (60-cycle) induction heating has grown. The smallest one at left would illustrate the largest billet heated five years ago (3" dia. x 11" long); in 1949 (6" x 24"); in 1951 (14" x 32"). At the extreme right, you see the giant billet (32" dia. x 80" long), which will be heated for the 20,000 ton Air Corps press.*

**Here's a brief brief on the advantages of a Magnethermic Heater for heating extrusion billets. Each billet temperature is measured and controlled automatically before moving into the press, eliminating chance of feeding a cold or underheated billet. Taper heat can be done when required. You eliminate all warm-up time. With a Magnethermic, you press a button and you're ready to go.**

**If you are thinking of installing an extrusion press, you can save many troublesome obstacles by discussing requirements with Magnethermic. Your inquiry will receive prompt attention.**

# Here's the most convenient way to make Refractory Concrete:



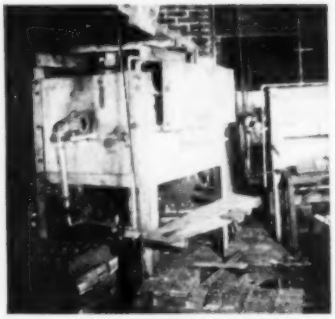


★ CAR TOPS

★ ARCHES ★ HEARTHS

★ SPECIAL SHAPES

★ CORE OVEN FLOORS



★ HEAT TREATING FURNACES

★ DOOR LININGS

**IT'S THAT SIMPLE**—Castable Refractories completely eliminate the need of finding suitable aggregates . . . and grading them to the right sizes. Packaged Castables come to you with Lumnite* calcium-aluminate cement and selected aggregates already mixed—needing only addition of water. The resulting Refractory Concrete reaches service strength in 24 hours or less.

This convenient way of making Refractory Concrete speeds work and cuts labor costs. It simplifies tough jobs—and some Castables are suitable for use at temperatures of 3000°F. or higher.

**REFRACTORY CONCRETE** made with Castables is the *adaptable* refractory. Easy to place in any size or shape.

No cutting or fitting necessary when you pour furnace walls, door linings and special shapes. There's no volume change to bother about. Build heat resistant floors, furnace walls, arches and hearths—Refractory Concrete withstands severe thermal shock, resists spalling.

In fact, you'll find Castables tailor-made for speed and convenience on many Refractory Concrete jobs. Handy for repairs, too.

**CASTABLES** to meet specific temperature and *insulation* requirements are made by manufacturers of refractories and sold by their distributors. For further information, write to LUMNITE DIVISION, Universal Atlas Cement Company (United States Steel Corporation Subsidiary), 100 Park Avenue, New York 17, N. Y.

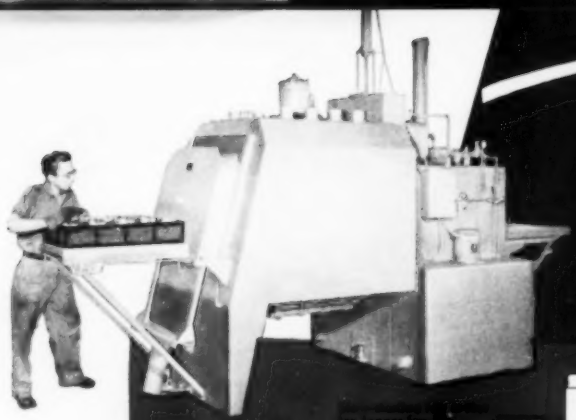
**"LUMNITE" is the registered trade mark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.*

MP-L-51R

**ATLAS® LUMNITE for INDUSTRIAL CONCRETES**

**REFRACTORY, INSULATING, OVERNIGHT, CORROSION-RESISTANT**

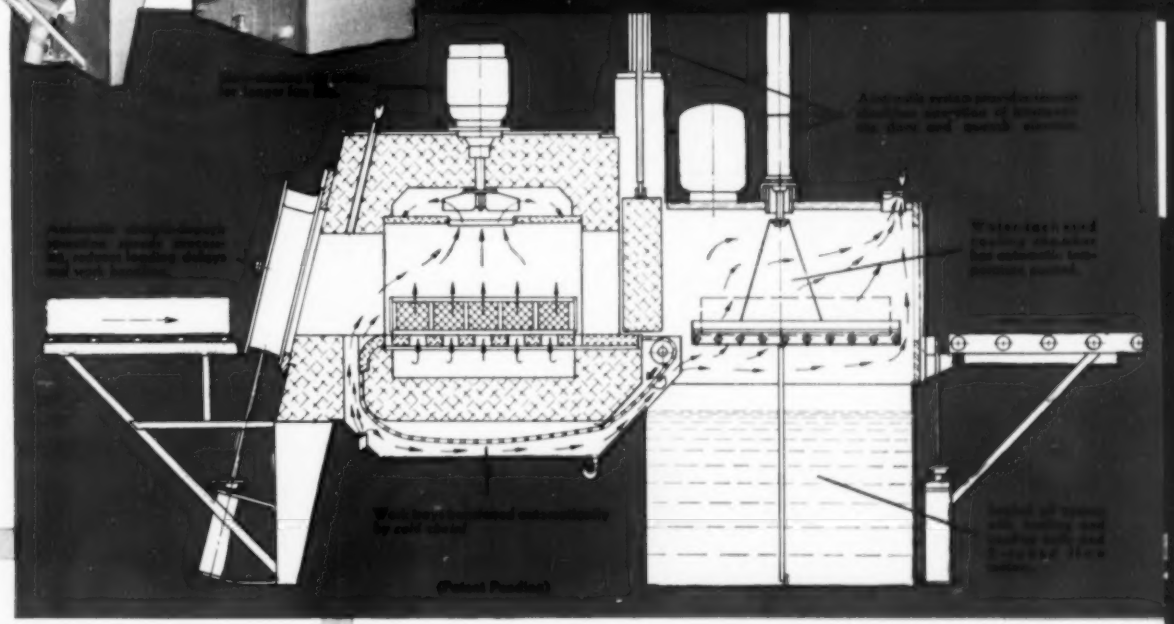
"THE THEATRE GUILD ON THE AIR"—*Sponsored by U. S. Steel Subsidiaries—Sunday Evenings—NBC Network*



# Now Ipsen

## 100% FORCED CONVECTION CONTROLLED ATMOSPHERE UNITS

**For Temperatures Up to 1850° F.**



1 Heat and quench signal lights
2 Automatic temperature recorder
3 Heating cycle timer
4 Quench timer
5 Hi oil flow timer
6 Selector switch for air or oil
7 Cycle start button

**SIMPLE CHANGE-OVERS**

Change-over from one process to another is simple, quick, and easy. Settings for heat, atmospheres, quench and oil flow is all that is required. Cycle is then controlled automatically.

★Above is a cross-section view of the Ipsen 400 Lb./Hr. Furnace showing the advanced design features which have made Ipsen the largest manufacturer of carbonitriding and batch-type heat treating units. With these new units, you get the advantages of 100% forced convection heating and controlled atmosphere processing, *plus* the full benefits of automatic straight-through operation. Thus, you eliminate loading delays and guess-work. You control distortion and get uniform results from batch to batch . . . today, tomorrow, or next year. You eliminate blasting and pickling operations and you can often use lower grade, less costly steels.

### A SINGLE UNIT HANDLES ALL OF THESE OPERATIONS

Unusually versatile, the Ipsen is built for temperatures up to 1850° F., and a single unit is equipped to handle all of the following processes:

| ATMOSPHERE COOLING | OIL QUENCHING |
|---|---|
| Normalizing | General Hardening |
| Stress Relieving | Carburizing and Hardening |
| Carburizing | Carbonitriding |
| Carbonitriding | Martempering |

***Send*** **Samples for Free Estimate** — find out how the new Ipsen Units can be applied to your job. Samples of your work will be run, procedures established in our new, modern lab, and cost estimates given without obligation.

***Write*** **for New Literature** — illustrates new design features, gives complete specifications of various units.

**MORE THAN 375 IPSEN HEAT TREATING UNITS ARE NOW SERVING INDUSTRY**

AUTOMATIC Ipsen

**IPSEN INDUSTRIES, INC. 723 South Main Street; Rockford, Illinois**

Universal Units to CARBONITRIDE • CARBURIZE • HARDEN • BRAZE • MARTEMPER • WASH • TEMPER

# FIRST PRECISION PART TO *MILLIONS OF HORSEPOWER*

## MIDVALE CRAFTSMEN PRODUCE GIANT TURBO GENERATOR SHAFT

The heart of the power conversion to electricity in America's dams is the huge shafts that carries the turbine blades and other essential parts. On its precision and long life depends millions of horsepower for homes, plants and factories of our country.

That is why Midvale craftsmen are called upon to produce huge turbo generator shafts similar to the one shown above — over thirty-four feet in length, ninety-six inches in diameter and machined to specifications.

Midvale precision and performance can supply all your needs for heavy equipment in industry. Pressure vessels for the petroleum and chemical industries . . . rolls for the paper and steel industry . . . rings for turbines and gears . . . forgings and heat and corrosion castings for all industries. If the job is big and the specifications exacting, you need the services of Midvale engineers and craftsmen.

**THE MIDVALE COMPANY**
NICETOWN, PHILADELPHIA 40, PENNA.
OFFICES: NEW YORK • CHICAGO • PITTSBURGH
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# MIDVALE

*Custom Steel Makers to Industry*

PRODUCERS OF FORGINGS, ROLLS, RINGS, CORROSION AND HEAT RESISTING CASTINGS

*you choose the fuel!*

**FOR MOST ECONOMICAL FLAMATIC SURFACE HARDENING**

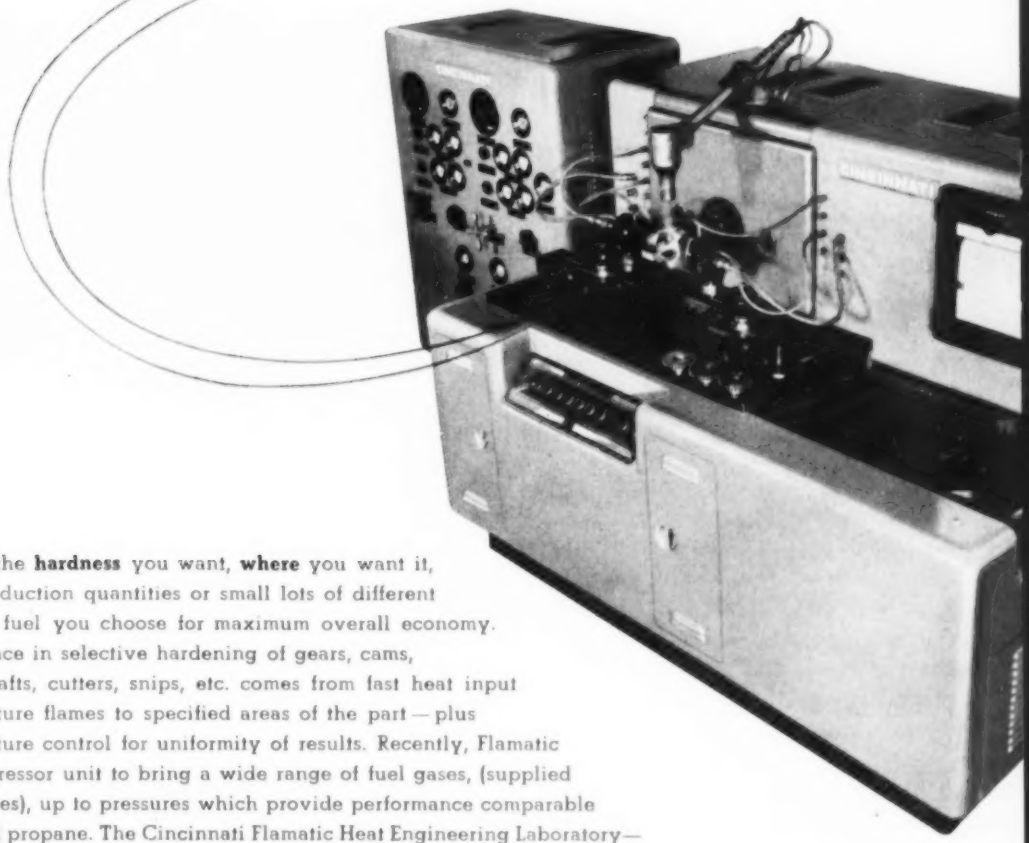
acetylene

propane

natural gas

manufactured gas

what have you?



Now you can get the **hardness** you want, **where** you want it, on either high production quantities or small lots of different parts, and use the fuel you choose for maximum overall economy. Flamatic performance in selective hardening of gears, cams, camshafts, crankshafts, cutters, snips, etc. comes from fast heat input with high temperature flames to specified areas of the part — plus electronic temperature control for uniformity of results. Recently, Flamatic developed a compressor unit to bring a wide range of fuel gases, (supplied at low line pressures), up to pressures which provide performance comparable with acetylene and propane. The Cincinnati Flamatic Heat Engineering Laboratory — now in a large new building — is better-than-ever staffed and equipped to analyze your surface hardening needs, experimentally Flamatic harden, and make practical recommendations.

**flamatic**

**THE CINCINNATI MILLING MACHINE CO.**

Cincinnati 9, Ohio, U.S.A. • CINCINNATI

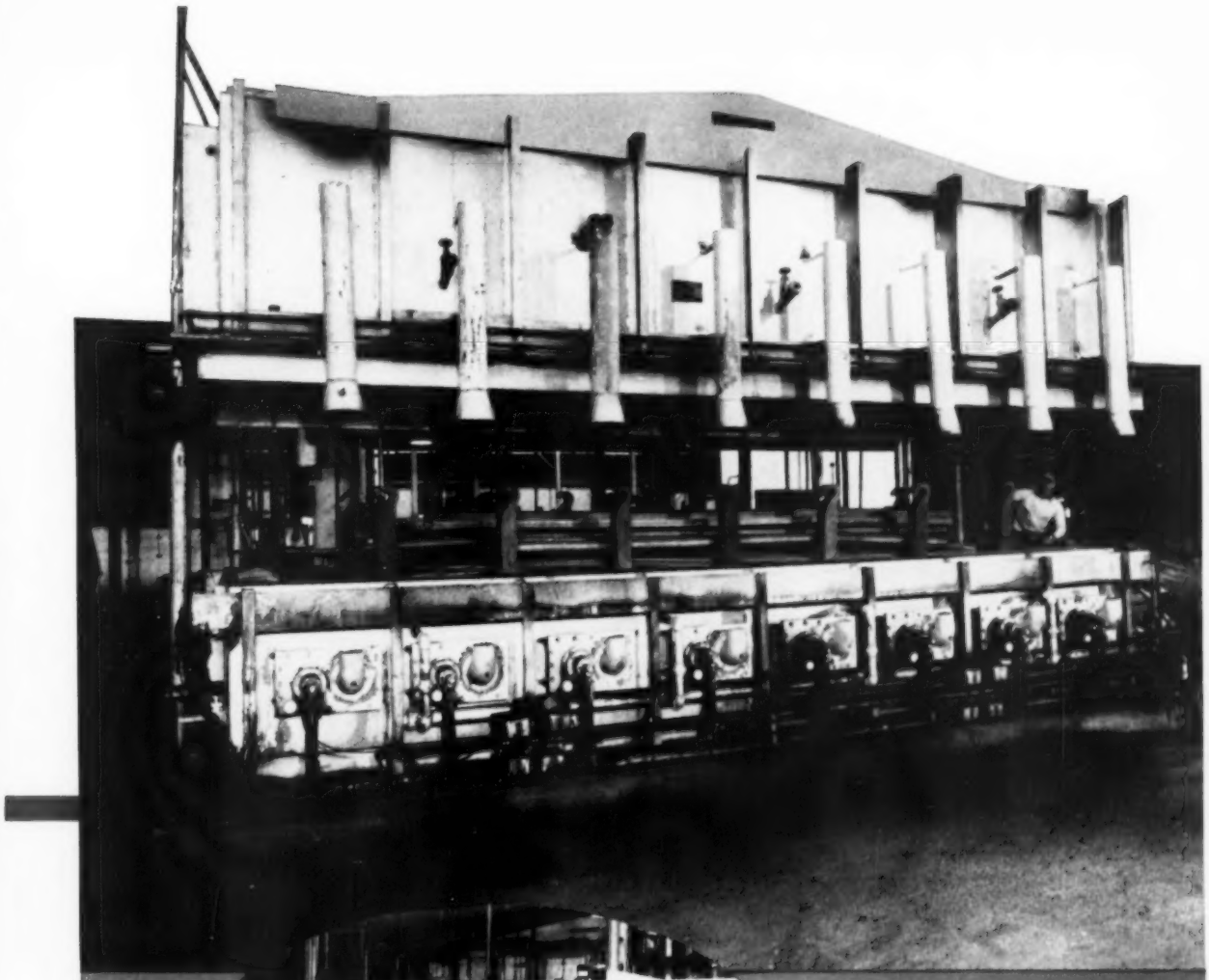
# "Investigated all types, Bought Westinghouse"

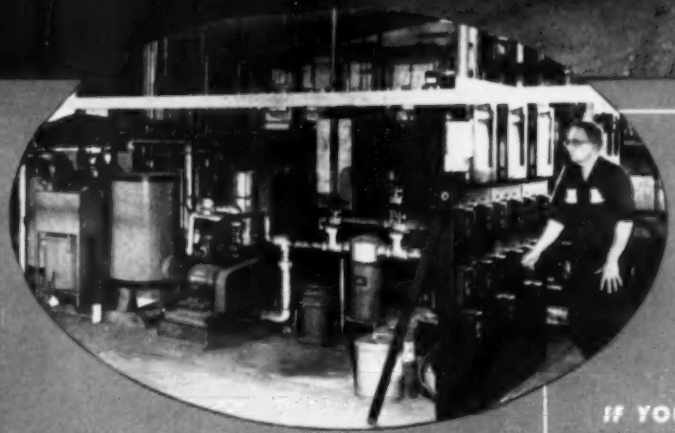
## ...says Leading Tool Steel Producer

"Our Westinghouse gas-fired rectangular bell furnace has greatly increased our production of high-quality steel. It enables us to meet stringent customer decarburization specifications. Rejects have been virtually eliminated. Several costly production operations have been reduced or are entirely avoided" . . . reports this leading producer of tool and specialty steels.

"We investigated all types before purchasing this furnace. In our opinion, Westinghouse was the best engineered, and offered the most atmospheric control on the market. To meet the demands for more production, we have just purchased another Westinghouse furnace."

Gas-fired or electric, there's a Westinghouse furnace to meet your heat-treating need. For tool-room application or continuous-line, high production, it's your assurance of an unbiased answer to your all-important problem. Get the facts from your Westinghouse representative. Write today for new 40-page book, B-5459, "Harnessing Heat." Westinghouse Electric Corporation, Industrial Heating Department, Meadville, Pa. J-10377





This three-zone heat control, used with the furnace above, produces more even annealing of bar stock, increases production, reduces unit cost.

IF YOUR PRODUCT CALLS FOR HEAT-TREATING...IT CALLS FOR A WESTINGHOUSE FURNACE ...GAS OR ELECTRIC

# Get all the facts

about the

# OLSEN

## STANDARD SUPER "L"

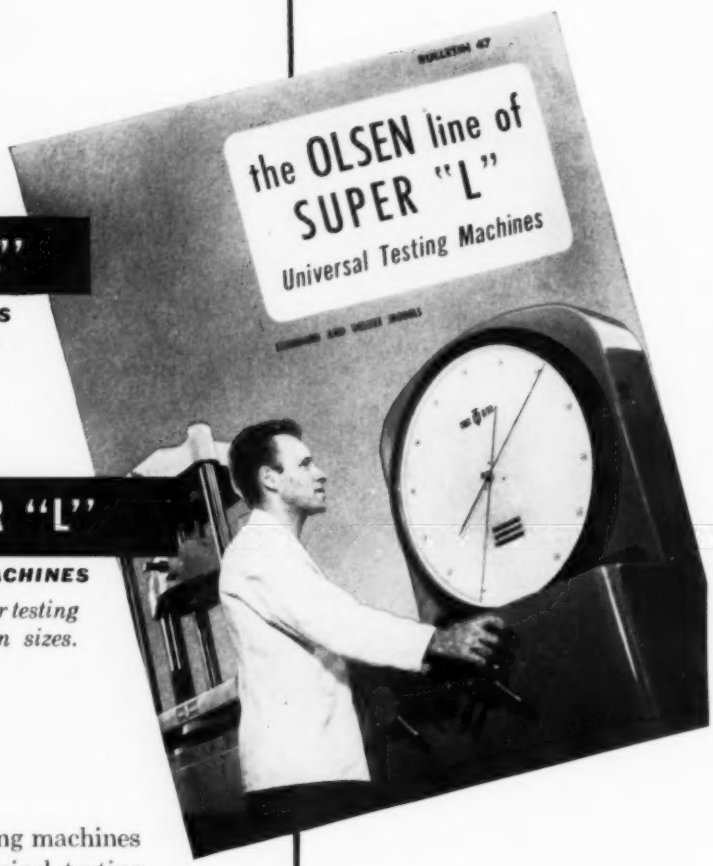
**UNIVERSAL TESTING MACHINES**

*Best buy for fast, accurate testing of standard sized specimens.*

## DELUXE SUPER "L"

**UNIVERSAL TESTING MACHINES**

*Greater clearances needed for testing a wider range of specimen sizes.*




Two complete lines of Super "L" testing machines that meet every requirement for physical testing. Featuring the exclusive Olsen SelecΦrange Indicating System . . . 50 to 1 spread of test ranges . . . instant change of ranges with flip of a switch while under test . . . and many more exclusive Olsen features.

***Full details in Bulletin 47***

***Write for your copy today!***

TINIUS OLSEN

***Testing & Balancing Machines***

**TINIUS OLSEN TESTING MACHINE CO.**

**2030 Easton Road · Willow Grove, Pa.**

# Superior Type 430 Stainless

## for heat applications

resists oxidation

does not corrode

fabricates easily

stays strong and tough

In the broad electric heating field, from domestic ranges to heavy-duty industrial units, Superior 430 Stainless enjoys time-tried favor. ● Used for trim rings, coil supports and medallions of range elements, this sturdy steel stays bright, stands up to heat, resists abrasion. As sheathing for high-temperature strip, ring, tubular and cartridge heaters, Superior 430 Stainless fabricates smoothly, easily and resists corrosion.

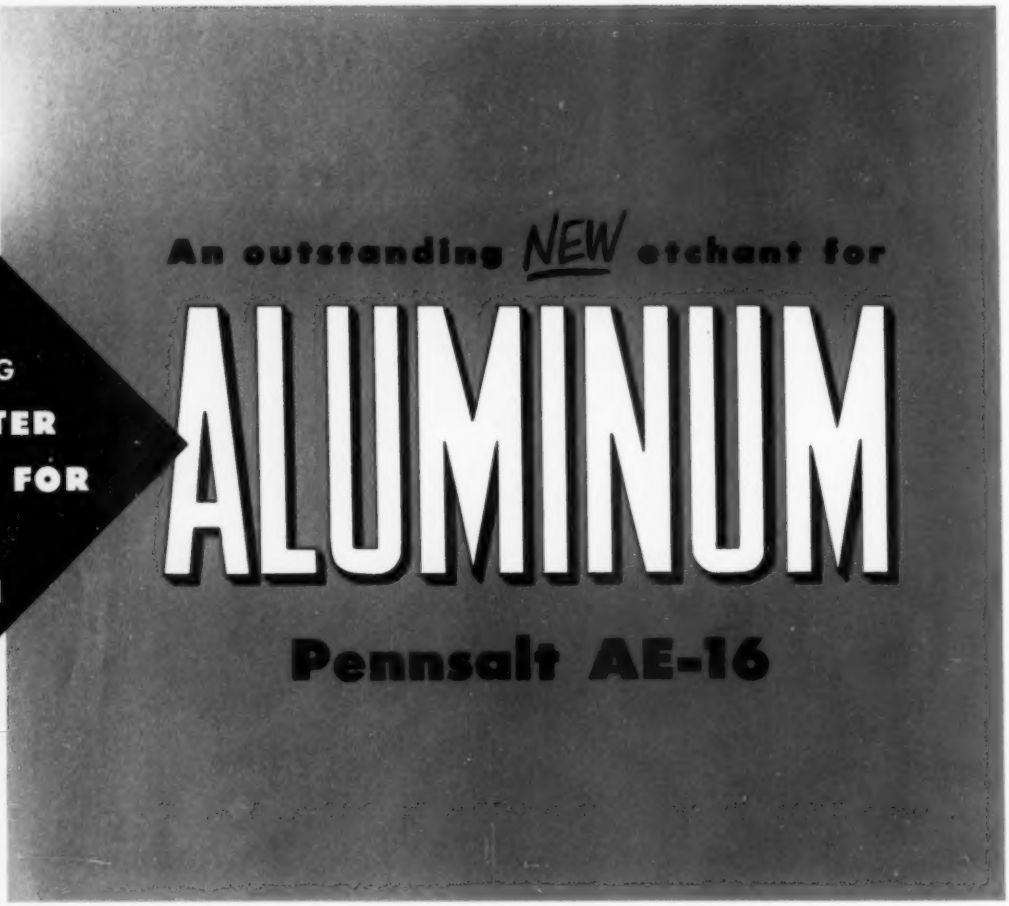
● Our 430 Stainless is available in easy handling coils. *Write!*

**Superior Steel**

CORPORATION

CARNEGIE, PENNSYLVANIA

MORE ON GETTING **A BETTER START FOR YOUR FINISH**




**non-sludging • non-scaling • long-lived • time-saving • money-saving**

Good news for fabricators! With Pennsalt's great new etchant—AE-16—you can give aluminum a beautiful satin finish *without* experiencing the usual headaches of sludge and scale—and at considerable lower cost than with *any* equivalent product!

**Here's a case in point:** A leading aluminum fabricator ran a side-by-side production test with AE-16 and an old-style etchant. After *nine weeks*, the original tankful of AE-16 had formed no sludge, was still performing satisfactorily! The old-style etchant had to be dumped and recharged twice in the same period.

Of course, AE-16's non-scaling characteristic means reduced tank maintenance costs, also. The AE-16 tank was cleaned by merely flushing it down with a hose—no chipping, no shoveling of rock-like scale.

**AE-16 is a *quality* etchant** In from one-half to ten minutes at normal tank temperatures, it produces a smooth, even, satin surface that easily conceals die marks and surface flaws. Few additions are required to keep up its working strength, and you'll find Pennsalt's method for determining the concentration exceptionally easy to follow.

All this means less down time, trouble-free operation, lower maintenance costs, increased production. Yet, even with its many advantages, *AE-16 actually costs less* than any comparable product on the market!

AE-16 is part of a complete aluminum preparation "package" Pennsalt now offers to fabricators. To help you use these excellent materials with maximum efficiency, Pennsalt also offers a Metal Processing Service, staffed by specialists in this field.

**Further information**—on AE-16 or on any of the other products in the Pennsalt "package"—is yours for the writing. Address: Metal Processing Service, Pennsylvania Salt Manufacturing Company, *East:* 285 Widener Building, Philadelphia 7, Pa. *West:* 2168 Shattuck Ave., Berkeley 4, Calif.

**The Pennsalt Aluminum "Package"**

**Pennsalt Cleaner A-27:** A new all-purpose non-etching cleaner that thoroughly removes all tough soils, including red and black marking inks. Rinses quickly and completely, even when allowed to dry on the work. Will not streak or stain.

**Pennsalt Aldox*:** A new powdered, acid-type desmutter and deoxidizer. Replaces nitric acid, does away with carboys and fumes.

**Pennsalt Cleaner #85:** An alkaline cleaner and deoxidizing agent recommended when aluminum is coated with a heavy layer of oil.

**Pennsalt Cleaner MC-1a:** An unusually economical general-purpose deoxidizing-type cleaner.

**Pennsalt Cleaner EC-51*:** A non-staining, organic-type emulsion cleaner.

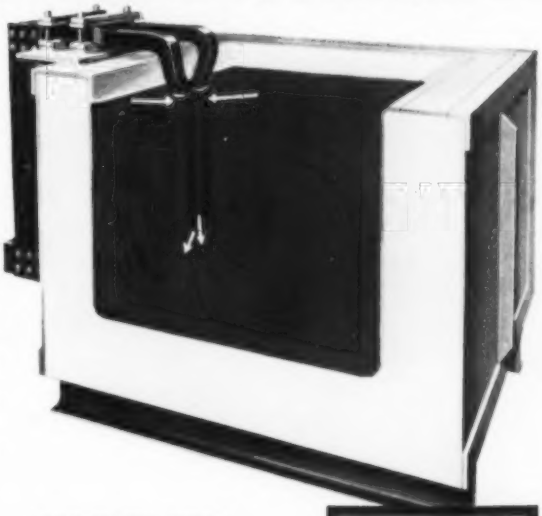
**Pennsalt Cleaner EC-54*:** An emulsion cleaner which will not boil off, evaporate, or flash at use temperatures.

*Trade Name of PSM Co.

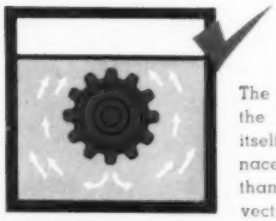
**Pennsalt Chemicals**

# THE MOST EFFICIENT HEAT TREATING PRINCIPLE

*...for* CARBURIZING • CYANIDE HARDENING NEUTRAL HARDENING • ANNEALING OR HARDENING STAINLESS STEEL • BRAZING • HARDENING HIGHSPEED STEEL • AUSTEMPERING • MARTEMPERING • PROCESS ANNEALING • CYCLIC ANNEALING DRAWING (TEMPERING) • SOLUTION HEAT TREATMENT • DESCALING • DESANDING • CLEANING

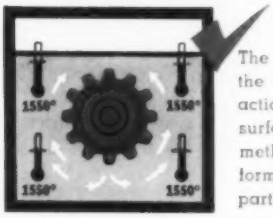


In the Ajax Electric Salt Bath, utilizing immersed electrodes, all heat is generated within the bath itself—the liquid salt acting as a "resistor". Electrodynamic forces produce vigorous circulation throughout the bath, in the *downward* motion indicated. This is precisely opposite to the *upward* thermal flow—dependent on a temperature difference in a bath—which exists in other salt bath furnaces. Only Ajax offers electrodynamic circulation!



## RAPID HEATING BY CONDUCTION

The rate of heating depends only on the heat conductivity of the work itself. Thus, the Ajax Salt Bath Furnace heats work 4 to 6 times faster than a radiation type or forced convection furnace.




## UNIFORM HEATING

The liquid salt completely surrounds the work and the automatic stirring action transmits uniform heat to all surfaces simultaneously. No other method delivers such heating uniformity—within 5° F. or *less* at any part of the bath.

## NO ATMOSPHERE PROBLEMS

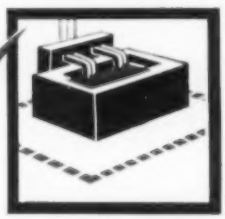
The Ajax Electric Salt Bath Furnace eliminates *all* atmosphere control problems. Scaling, oxidation and decarb are avoided. First cost of gas generating equipment as well as its operating expense are eliminated.

## AUTOMATIC PREHEATING

When a cold piece of metal is immersed, a "cocoon" of frozen salt forms around it instantly. This layer serves as a temporary insulator, preventing temperature shock and too sudden heating. The frozen salt melts in a minute or less and the work then heats rapidly to bath temperature.

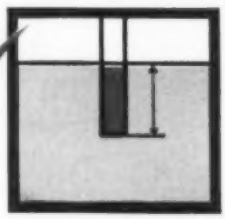
## BUOYANCY THAT MINIMIZES DISTORTION

Although the work sinks readily into the liquid salt, the bath nevertheless supports it to a marked degree. In effect, the work weighs appreciably less when immersed and this tends to prevent distortion and warpage.



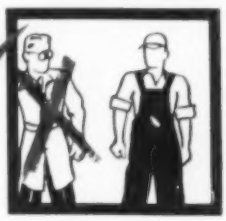
## MORE PRODUCTION IN LESS FLOOR SPACE

Because an Ajax furnace heats work so much faster—and because it eliminates the need for atmosphere generators and similar bulky auxiliary equipment, a proportionately smaller amount of floor space is required to handle a given volume of work.



## SELECTIVE HEATING

Because of its rapid heating rate, only that portion of the work immersed in the bath is heated. Just dip and treat *any desired portion* of any metal part or assembly.



## NO SKILLED LABOR

Operation is so entirely automatic, so closely controlled by the Ajax furnace itself, that even an unskilled operator can handle full production.

*72 pages of factual heat treating data! Write for Catalog 116 on your company stationery.*

# AJAX ELECTRIC SALT BATH FURNACES

**AJAX ELECTRIC COMPANY, INC.** 910 Frankford Ave., Philadelphia 23, Pa.
**The World's Largest Manufacturer of Electric Heat Treating Furnaces Exclusively**

*Whether you purchase by the drum*

*or carload...*

# NOW-AS ALWAYS-

## YOU PAY NO EXTRA PREMIUM FOR NIALK® TRICHLORethylene's TOP QUALITY

Always a top quality product, NIALK TRICHLORethylene is your best buy for efficient, economical, metal degreasing. Niagara Alkali has never charged a premium price for NIALK TRICHLORethylene.

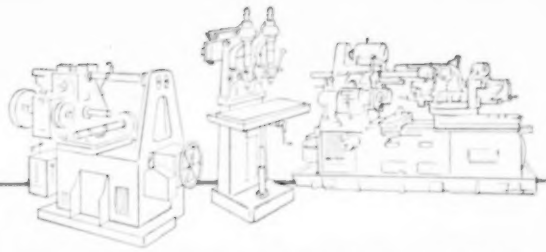
As always, you receive a high purity, high performance product with these special advantages:

- **Cleans and dries in record time**
- **Requires less power consumption**
- **Has minimum vapor loss**
- **Is non-flammable . . . stable**

Make sure your metal parts are 100% grease-free. NIALK TRICHLORethylene leaves them clean, warm, dry, ready for immediate electroplating, painting, enameling, lacquering, rustproofing, heat treating, pickling, inspection, assembling.

**NIAGARA ALKALI COMPANY**
60 East 42nd Street, New York 17, N. Y.

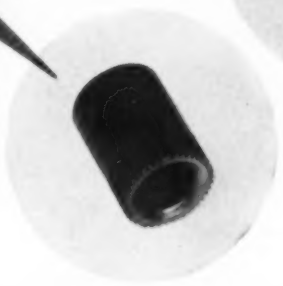
NIALK Liquid Chlorine • NIALK Caustic Potash • NIALK Carbonate of Potash • NIALK Paradichlorobenzene
NIALK Caustic Soda • NIALK TRICHLORethylene • NIAGATHAL® (Tetrachloro Phthalic Anhydride)

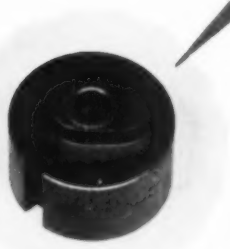


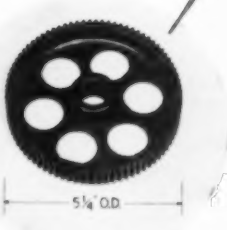
**YOU DON'T ALWAYS NEED MACHINE TOOLS FOR FINISHED MACHINE PARTS**

## *Specify* OILITE

PRODUCTS OF SINTERED METALS








**With OILITE YOU:**

- Eliminate Machine Tools
- Eliminate Tooling Programs
- Conserve Skilled Man Hours
- Conserve Strategic Material
- Get Quick Delivery

**Other OILITE Advantages Include:**

- Over 20 Years Production Experience
- An Alternate Material
- Engineered Products
- No Machining
- Low Price
- Release Skilled Man Power For Other Jobs

**Field Engineers and Depots throughout U. S. and Canada**

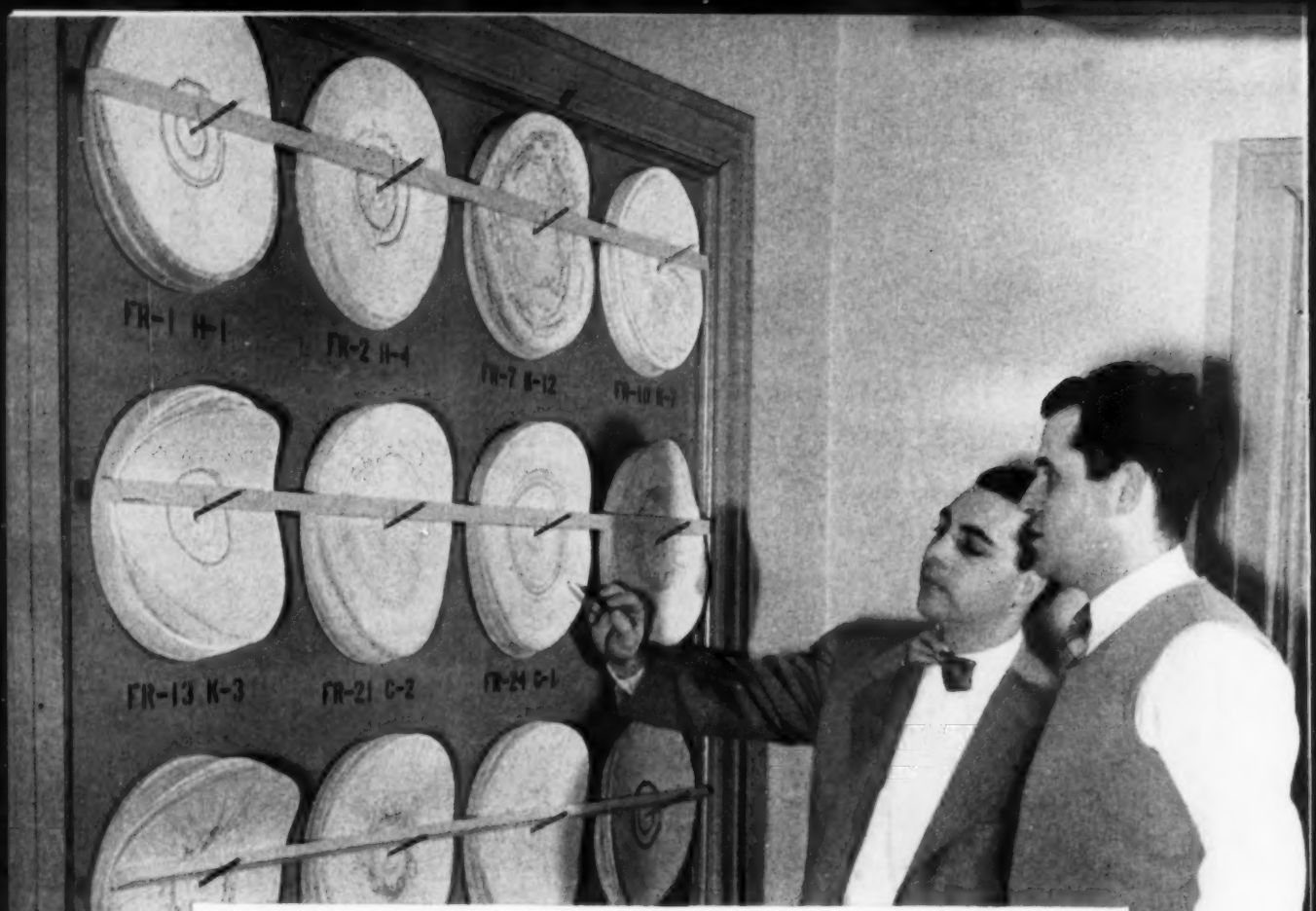
SINTERED OILITE PRODUCTS

**AMPLEX MANUFACTURING COMPANY**

*Subsidiary of Chrysler Corporation*

**Detroit 31, Michigan**

*Oilite Products include: BEARINGS, Finished Machine Parts, Cored and Solid Bars, Permanent Filters, and Special Units.*




# Here's why it pays *to know your*

**HSM**
HONEYWELL SUPPLIES MAN

L. E. DOTTS, Honeywell Supplies Man in the East Orange, N. J. area, points out features of Brown instrument charts to Mr. James Forgione of the Heyden Chemical Corporation . . . explains that they're made of paper designed for clear, consistent inking, precisely calibrated for accurate recording.

Planned buying, the HSM way, eliminates excessive storage time that often leads to chart moisture damage. And it helps you save money and maintain balanced inventories . . . not only on charts, but on *all* pyrometer supplies.

Get the full details from your local Honeywell Supplies Man, at your nearby Honeywell office . . . as near to you as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4503 Wayne Ave., Philadelphia 44, Pa. Immediate shipment from Philadelphia stocks.

MINNEAPOLIS
**Honeywell**
BROWN INSTRUMENTS
*First in Controls*

# Facts about *HELI-COIL* inserts you should know

*What they are*

*Heli-Coil** screw thread inserts are precision formed coils of stainless steel or phosphor bronze wire. Wound into tapped holes, they form permanent, non-corrosive, strip-proof threads of astonishing strength. Available for National Coarse, National Fine and Unified threads, pipe threads and spark plug threads. They are made in all standard sizes and lengths for assemblies requiring Class 3, 3B, 2 or 2B fits.

*What they are for*

AS ORIGINAL COMPONENTS: *Heli-Coil* inserts are used to provide stronger, lighter fastenings, corrosion-proof, wear-proof threads in all assemblies.

FOR PRODUCTION SALVAGE: When conventional tapped holes are damaged in production, restore them on the line with *Heli-Coil* inserts. Get better-than-original strength with no increase in screw size and no tell-tale signs of rework.

FOR SPEEDY REPAIRS: When tapped threads wear, strip or corrode in service, renew them in minutes on location in shop or field with *Heli-Coil* inserts. No welding—no plugging—no secondary machining—no oversize screws.

*How they work*

Holes are drilled and tapped as you do for ordinary threads—then *Heli-Coil* inserts are wound into tapped holes by hand or power tools. Install in a few seconds, assure thread protection forever. Can be used in any metal wood or plastic.

*No other method is so simple, effective and practical.*

*What they do for you*

*Heli-Coil* inserts *save money* because they strengthen threads and make *fewer* smaller fastenings do the same holding job. They make *lighter* bosses and flanges practical and they *save weight* in two ways: (1) by permitting use of cap screws, instead of bolts and nuts; (2) by allowing use of smaller, shorter, fewer cap screws. *Heli-Coil* inserts *protect* your product from thread wear, galling and stripping for life in every kind of metal, in plastics or wood. They preserve customer good-will by preventing product failure, due to thread fault. *Heli-Coil* inserts improve the end product, cut rejects, salvage threading errors.

Best time to put *Heli-Coil* inserts benefits to your use is right at the designing board, as many leading manufacturers are doing. But to convince you of their many advantages ask for a working demonstration right on your production line. Write today! Complete information and engineering data is available in the *Heli-Coil* catalog. Use Coupon!

*Reg. U.S. Pat. Off.

***Approved for All Military and Industrial Uses***

# 7 savings wrapped up in HELI-COIL inserts

***These savings are multiplied into major profits this simple way***

Use *Heli-Coil** Inserts to:

1. *Save* money by using fewer and smaller screws to do the same holding job.
2. *Save* material—lighter bosses, thinner wall section, smaller flanges.
3. *Save* weight and reduce bulk in assemblies.
4. *Save* assembly time by using cap screws instead of nut-and-bolt assemblies.
5. *Save* rejections in production. Threads damaged on the line are quickly repaired. You save time. Reduce scrap.
6. *Save* on field service costs. No field damage to threads—fortified by *Heli-Coil* inserts.
7. *Save* customer good will by eliminating product failure due to thread fault. Every thread in your product is made stronger, longer wearing with *Heli-Coil* insert protection.

**Use the handy coupon to get *free sample Heli-Coil* inserts plus all the data you need to design these savings into your product.**

**HELI-COIL CORPORATION**
265 SHELTER ROCK LANE, DANBURY, CONN.

☐ Send samples and Handbook 652, a complete design manual.
☐ Send samples and put my name on list to receive "Heli-Coil," case history periodical.

NAME _____ TITLE _____

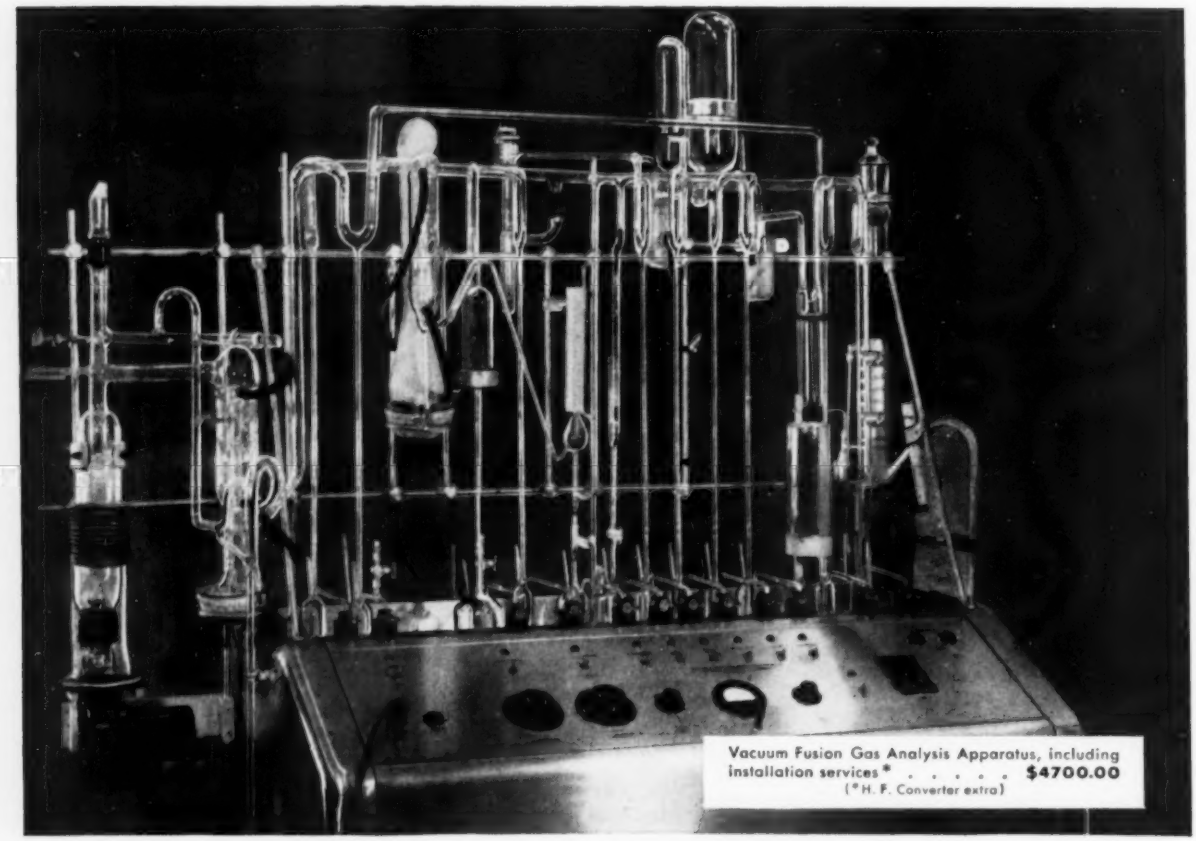
COMPANY _____

ADDRESS _____

CITY _____ ZONE _____ STATE _____

# Vacuum Fusion Gas Analyzer

***with complete installation and instruction***



Vacuum Fusion Gas Analysis Apparatus, including installation services* . . . . . $4700.00
(*H. F. Converter extra)

## A packaged unit to determine the content of oxygen, nitrogen and hydrogen in metals

A wide variety of metals and alloys, including titanium, can be analyzed to determine the amount of oxygen, nitrogen and hydrogen contained either as combined or dissolved gas, in the range from one per cent to approximately $10^{-4}$ per cent by weight.

Total gas contents of titanium are reported within approximately the same range for oxygen and hydrogen as for other metals.

The apparatus incorporates the best features and techniques reported in the literature or known to our laboratory and has been employed for some time in connection with our own metallurgical research activities.

Operating procedure is relatively simple and can be readily mastered. Installation, final testing and instruction of your operator is performed by one of our trained analysts.

Write for details of Type 09-1240 Vacuum Fusion Gas Analysis Apparatus.

**ANALYTICAL SERVICE**

Write for information about NRC Gas Analysis Service if your requirements do not justify the purchase of an instrument.

INDUSTRIAL RESEARCH • PROCESS DEVELOPMENT
HIGH VACUUM ENGINEERING AND EQUIPMENT

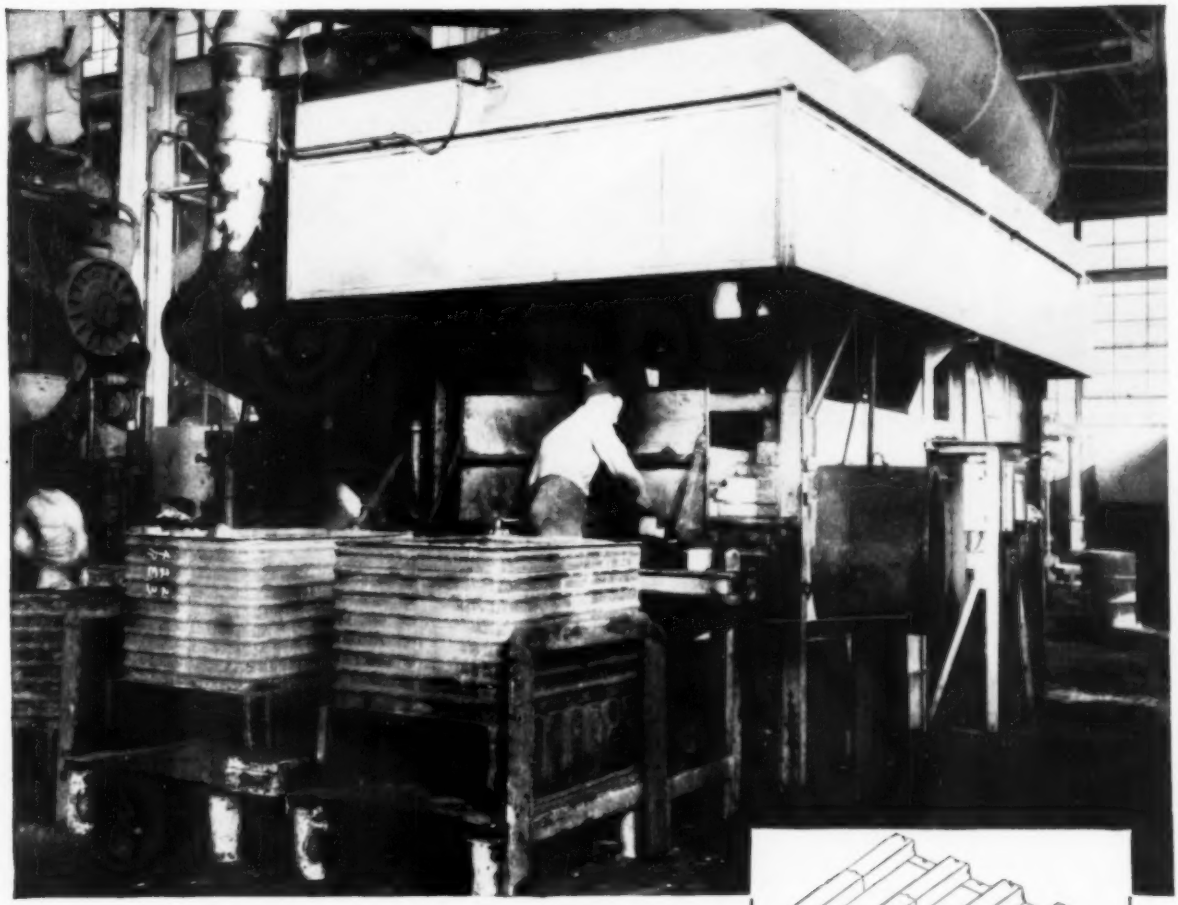
NRC

METALLURGY • DEHYDRATION • DISTILLATION
COATING • APPLIED PHYSICS

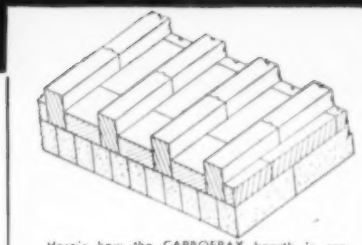
National Research Corporation

EQUIPMENT DIVISION

*Seventy Memorial Drive, Cambridge, Massachusetts*



# Silicon carbide outlasts chrome hearth 3 to 1



Here's how the CARBOFRAX hearth is constructed. The skid rails act as guides, making in effect, a hearth with several separate channels.

This is a pusher-type forge furnace, one of four operated by an automotive company. Steel slugs 4" x 4" x 5", weighing 16 lbs., are heated to 2250 F, and every hour, roughly 250 are pushed through.

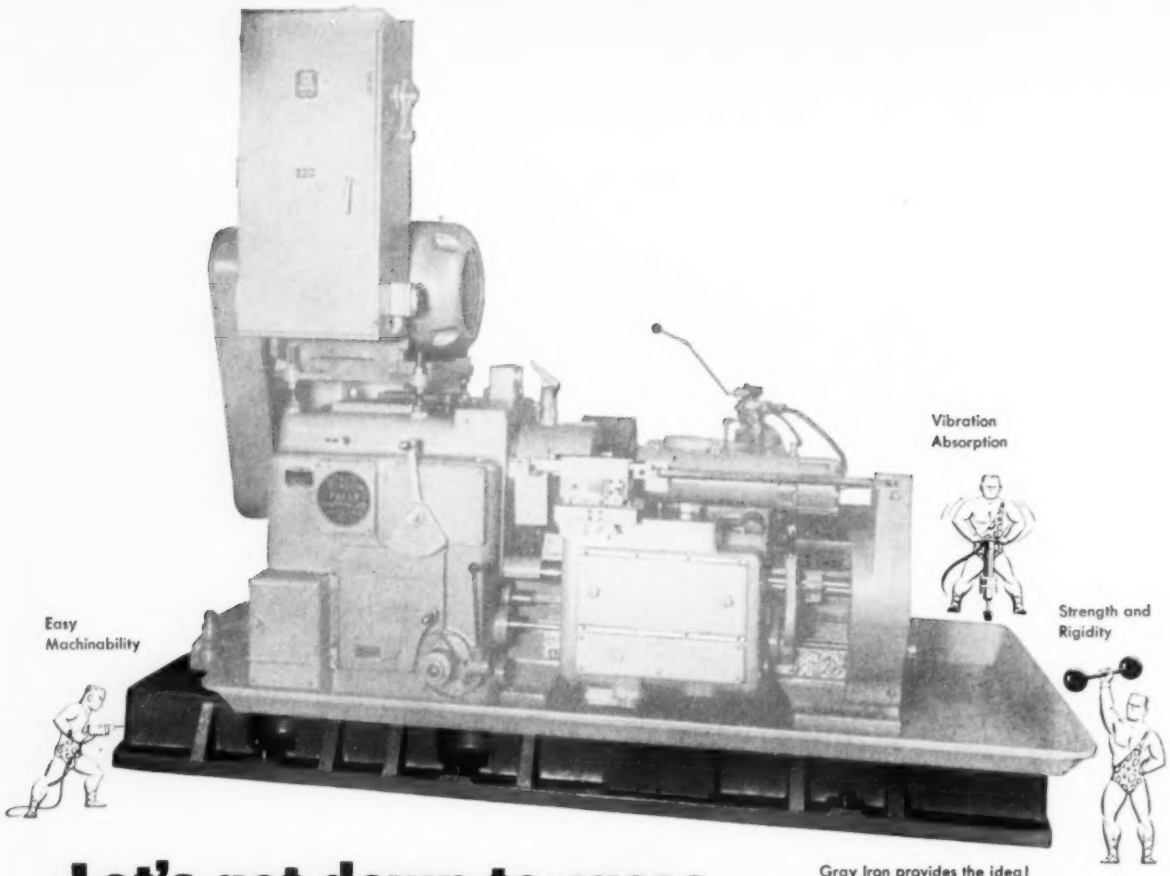
The rammed, chrome-ore hearths they formerly used, wore out rapidly under this abrasion and heat. At most, they lasted three months. Interim repairs were often needed, too, mostly on the hot end.

Then, they put in a channel-type hearth (see drawing) made of one of the hardest, most abrasion-resistant materials in existence — CARBOFRAX® silicon carbide refractory. As a result, they now get an *average of nine months life*, and need few or no repairs.

Now that their hearths last three times longer, their labor, material, and down-time costs have naturally been reduced proportionately — sizeable savings, all. And all savings that other companies have duplicated. Interested? It costs nothing to check up. Simply address: Department C-53, Refractories Division, The Carborundum Company, Perth Amboy, New Jersey.

**CARBORUNDUM**

Registered Trade Mark




Gray Iron provides the ideal combination of characteristics for the base of this automatic lathe.

# Let's get down to cases ABOUT BASES!

***GRAY IRON Characteristics Include:***

- Castability
- Low Notch Sensitivity
- Heat Resistance
- Durability
- Machinability
- Rigidity
- Wear Resistance
- Corrosion Resistance
- Vibration Absorption
- Wide Strength Range

The manufacturer of this automatic lathe had previously used a fabricated steel base. To cut down delivery time and reduce costs, a switch was made to a cast Gray Iron base.

In the manufacturer's own words . . . "in addition to appreciable cost savings, delivery time to our machine shop is about one-eighth that of fabricated steel. Because of the rigidity inherent in the casting, we have a base which is easy to machine, absorbs vibration, and does the kind of a job our customers expect."

When you "get down to cases" about machine tool bases—or any other application requiring the unique combination of advantages listed at the left—be sure to investigate Gray Iron! Write for technical information on the many advantages of the Gray Iron casting process.

***Make it Better with Gray Iron*** • **Second largest industry in the Metal-working field**

**GRAY IRON FOUNDERS' SOCIETY, INC.**

*NATIONAL CITY-E. 6th BLDG., CLEVELAND 14, OHIO*

TABLE II - PHYSICAL PROPERTIES OF HOUGHTON'S LIQUID BATHS

| Type | Product | Melting Point °F. | Working Range °F. | Specific Heat (At Oper. Temp.) | Specific Gravity (At Oper. Temp.) | Unit Weight Liq. (lbs. per cu. ft.) | Liquidity (Drag-out gr. per sq. inch) |
|---|---|---|---|---|---|---|---|
| Liq. Carb. | Perliton Liq. Heat | 1220 | 1350-1675 | 0.4-0.3 | 1.60 approx. | 100 @ 1550 | 0.075-0.100 @ 1500 approx. |
| " " | " 11 | 1240 | | | | | |
| " " | " 45 | 1210 | | | | | |
| " " | " 60 | 1170 | 1350-1750 | 0.4-0.3 | 1.60 approx | 100 @ 1550 | 0.075-0.100 |
| Reheat | Perlitex 30 | 960 | 1050-1550 | 0.4-0.3 | 1.60 approx | 100 @ 1400 | 0.017 @ 1450 |
| " | " 50 | 940 | | | | 95 @ 1400 | 0.013 @ 1450 |
| " | " 75 | 1000 | | | | 88 @ 1400 | 0.075 @ 1450 |
| Carbonate | Liquid Heat 300 | 1040 | 1150-1700 | 0.442 | 1.90 | 119 @ 1500 | 0.025 @ 1500 |
| Neutral | Liquid Heat N.D. | 1200 | 1300-1700 | 0.171 | 2.65 | 165 @ 1550 | 0.075 @ 1500 |
| " | " " 168 | 1240 | 1350-1650 | 0.263 | 1.60 | 100 @ 1350 | 0.020 @ 1500 |
| " | " " 800 | 950 | 1025-1400 | 0.16 | 2.19 | 137 @ 1250 | 0.06 @ 1100 |
| " | " " 980 | 980 | 1100-1650 | 0.158 | 2.24 | 140 @ 1250 | 0.04 @ 1250 |
| " | " " 1145 | 1200 | 1300-1650 | 0.26 | 1.60 | 100 @ 1350 | 0.020 @ 1550 |
| " | " " 1185 | 980 | 1050-1350 | 0.30 | 2.15 | 130 @ 1200 | 0.027 @ 1200 |
| " (S.Stl) | " " 1450 | 1450 | 1550-1950 | 0.165 | 3.00 | 187 @ 1600 | 0.075 @ 1800 |
| H.S. Steel | Liquid Heat 1550 | 1550 | 1650-2350 | 0.163 | 2.88 | 180 @ 2100 | 0.070 @ 2100 |
| " " | " " Q-1138 | 875 | 920-1450 | 0.33 | 1.68 | 105 @ 1200 | 0.028 @ 1200 |
| " " | " " 720 | 875 | 950-1450 | 0.28 | 1.83 | 114 @ 1200 | 0.03 @ 1200 |
| Nitrate | Draw Temp 275 | 275 | 350-1000 | 0.36 | 1.76 | 110 @ 800 | 0.016 @ 900<br>0.052 @ 600 |
| " | " " 430 | 430 | 550-1100 | 0.38 | 1.84 | 115 @ 800 | 0.017 @ 900<br>0.052 @ 600 |
| " | Mar-Temp Salt | 285 | 350-1000 | 0.36 | 1.92 | 120 @ 400 | 0.065 @ 400 |
| Neutral | Draw Temp 800 | 950 | 1025-1400 | 0.16 | 2.19 | 137 @ 1250 | 0.06 @ 1100 |
| Brazing | Liquid Heat 110 | 1450 | 1550-2100 | 0.166 | 3.01 | 187 @ 1600 | 0.075 @ 1800 |
| " | Liquid Heat 111 | 1200 | 1300-1800 | 0.172 | 2.66 | 165 @ 1550 | 0.075 @ 1500 |

# *Add a dash of HOUGHTON "KNOW-HOW" and get the UNIFORM RESULTS you need!*

• A valued ingredient that is not in the formula goes with every Houghton salt you buy—Houghton's wide knowledge of your heat treating problems.

It's the factor which adds extra assurance that your salt bath will be *right* for the job . . . that your heat treated metal will have the precise physical properties you require . . . that you'll be able to maintain the bath so as to get uniform results day after day.

In Houghton's 32-page "Liquid Salt Baths" book, you'll find proof of the benefits you get by using Houghton salts combined with Houghton experience. It shows you how to obtain faster, surer heat treating with salts. Ask the Houghton Man for a copy, or write to E. F. Houghton & Co., Philadelphia 33, Pa.

HEAT TREATING SALTS
*. . . a product of*

**E. F. HOUGHTON & CO.**
PHILADELPHIA · CHICAGO · DETROIT · SAN FRANCISCO

***Ready to give you on-the-job service . . .***

*MCA offers Quick delivery*

# of all forms for all uses

## TUNGSTEN

Ferro-Tungsten

Tungstic Oxide

Tungstic Acid

Ammonium Para-Tungstate

Sodium Tungstate

Tungsten Metal Power

Now that Tungsten high-speed steel can be supplied as needed, manufacturers are returning to it for the well-defined uses in which it surpasses all other materials.

Since Government restrictions have eased, the volume of Tungsten used for civilian requirements has increased month by month. An informative book, entitled "Tungsten Steels," has been prepared by the Molybdenum Corporation. It deals with both scientific and practical considerations, and recommends procedures found to yield best results. A copy will be mailed on request.

As recognized authorities in the application of Molybdenum, Tungsten, Boron, Rare Earths, and the alloys and chemical elements of these materials, MCA assures confidential and immediate response to inquiries.

# MOLYBDENUM

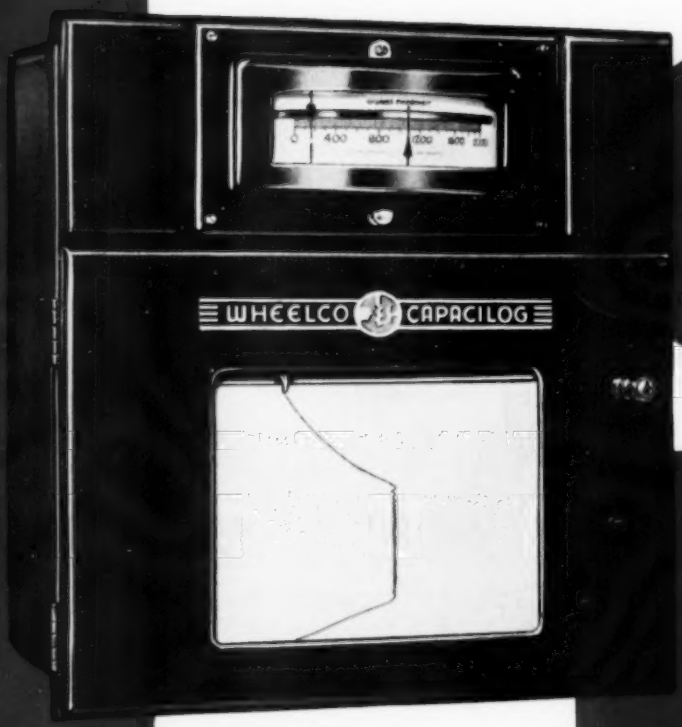
## CORPORATION OF AMERICA

**Grant Building** **Pittsburgh 19, Pa.**

*Offices:* Chicago, Cleveland, Detroit, Los Angeles, New York, Pittsburgh, San Francisco
*Sales Representatives:* Edgar L. Fink, Detroit; Brumley-Donaldson Co., Los Angeles, San Francisco
*Subsidiary:* Cleveland-Tungsten, Inc., Cleveland, Ohio

MCA

# engineered simplicity




## capacilog STRIP CHART recorder

**instantaneous "no contact" controlling**

**Single Point Electronic Strip Chart Recorder-Controller**

Engineered simplicity gives operating accuracy and mechanical stamina to Capacilog Recorder-Controllers.

Elimination of mechanical clamping mechanism between indicating pointer and control unit allows instantaneous recording action. Design simplicity confines moving parts to a minimum; maintenance is easy, mechanical wear is negligible. An added convenience is the plug-in chassis for facilitating quick replacement.

Capacilog strip chart Recorders are available with either high or low temperature measuring systems for electrical or pneumatic control. Write for Bulletin C2-2.

### CAPACILOGS IN INDUSTRY

Capacilog Installation on Draw Furnace at Hotpoint Incorporated, Milwaukee, Wis.

**A Precision Product of Wheelco Instrumentality**

BARBER COLMAN

## wheelco instruments division

**BARBER-COLMAN COMPANY • ROCKFORD, ILLINOIS, U. S. A.**

1225 ROCK STREET

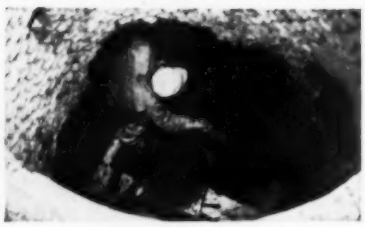
Instrumentality

# Johns-Manville Insulations save industry a billion dollars in fuel every year!

## Reduce your fuel costs and build better furnace linings with JM-3000 INSULATING FIRE BRICK

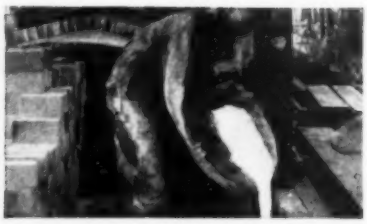
HERE'S THE ONLY insulating fire brick that withstands a full 3000F. It's highly efficient both as an exposed refractory lining or as back-up insulation. And JM-3000 is only one of six types of Johns-Manville Insulating Fire Brick made for these applications. All provide long-life insulation. All are light in weight, have low conductivity, high structural strength. These properties permit thinner furnace walls—yet you can achieve important fuel savings and increased production, because J-M Insulating Fire Brick assures quick furnace response.

**Sil-O-Cel* Insulating Brick** is another outstanding J-M fuel-saver . . . a high load-bearing brick for back-up insulation behind refractory linings. It comes in three types, for service through 2500F—makes it possible to reduce the necessary thickness of refractory linings as much as one-third.



**Save fuel with J-M Hydraulic Setting Refractories**

Johns-Manville refractories meet every need for castable, troweling and gunning applications for temperatures through 3000F. *Firecrete** is used to cast special shapes of all kinds. It is ready for use within 24 hours, has negligible shrinkage and high resistance to spalling. *Blazecrete** is used to build and repair furnace linings. When gunned, it adheres readily with a minimum of rebound loss. When slap-troweled, it eliminates laborious ramming and tamping.

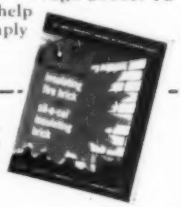


**Save Fuel with J-M Aggregates and Fills**

These lightweight insulations are used as fills to conserve heat in irregular spaces where other forms of insulations cannot be economically applied. They are also used as aggregates for mixing with other materials to form insulating refractory concrete.

*Reg. U. S. Pat. Off.

**Send for your free copy!** This new booklet IN-115A gives full details about J-M insulating materials for service through 3000F. To find out how they can help cut your fuel costs, simply mail coupon.



JOHNS-MANVILLE JM PRODUCTS

**Johns-Manville**

***FIRST IN* INSULATION**

Johns-Manville, Box 60, N.Y. 16, N.Y.
(In Canada, 199 Bay St., Toronto 1, Ont.)
Please send me, without charge, copy of brochure IN-115A

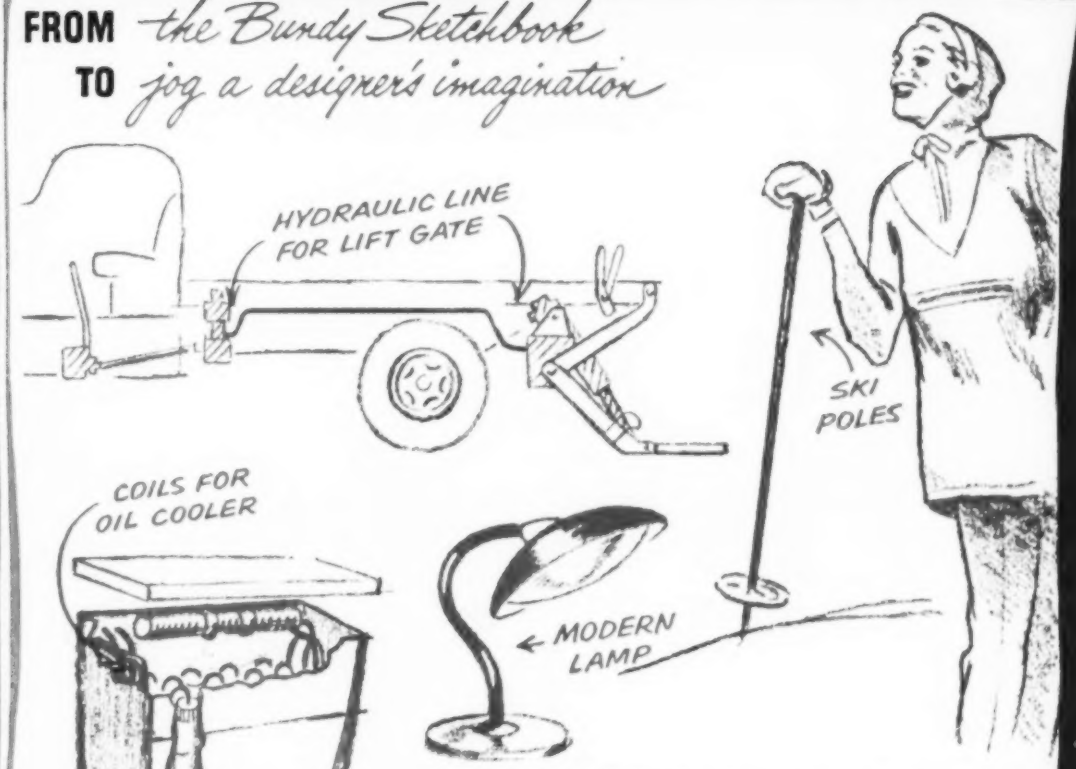
Name_____

Company_____

Street_____

City & Zone_____ State_____

**FROM** *the Bundy Sketchbook*
**TO** *jog a designer's imagination*




*REMARKS* Need tubing that will do a better job for you? Look into Bundyweld. Need fabricated tubing parts? Let us tell you about Bundy's unmatched facilities. Need engineering help? Let us show you what we can do.

WRITE → today for catalog or for help in developing your idea for a tubing application.

BUNDY TUBING CO., DETROIT 14, MICH.

# Bundyweld Tubing

® DOUBLE-WALLED FROM A SINGLE STRIP

**Leakproof**
**High thermal conductivity**
**High bursting point**
**High endurance limit**
**Extra-strong**
**Shock-resistant**
**Ductile**

**Lightweight**
**Machines easily**
**Takes plastic coating**
**Scale-free**
**Bright and clean**
**No inside bead**
**Uniform I.D., O.D.**

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Bundyweld starts as a single strip of copper-coated steel. Then it's . . . continuously rolled twice around laterally into a tube of uniform thickness, and passed through a furnace. Copper coating fuses with steel. Result . . . Bundyweld, double-walled and brazed through 360° of wall contact.

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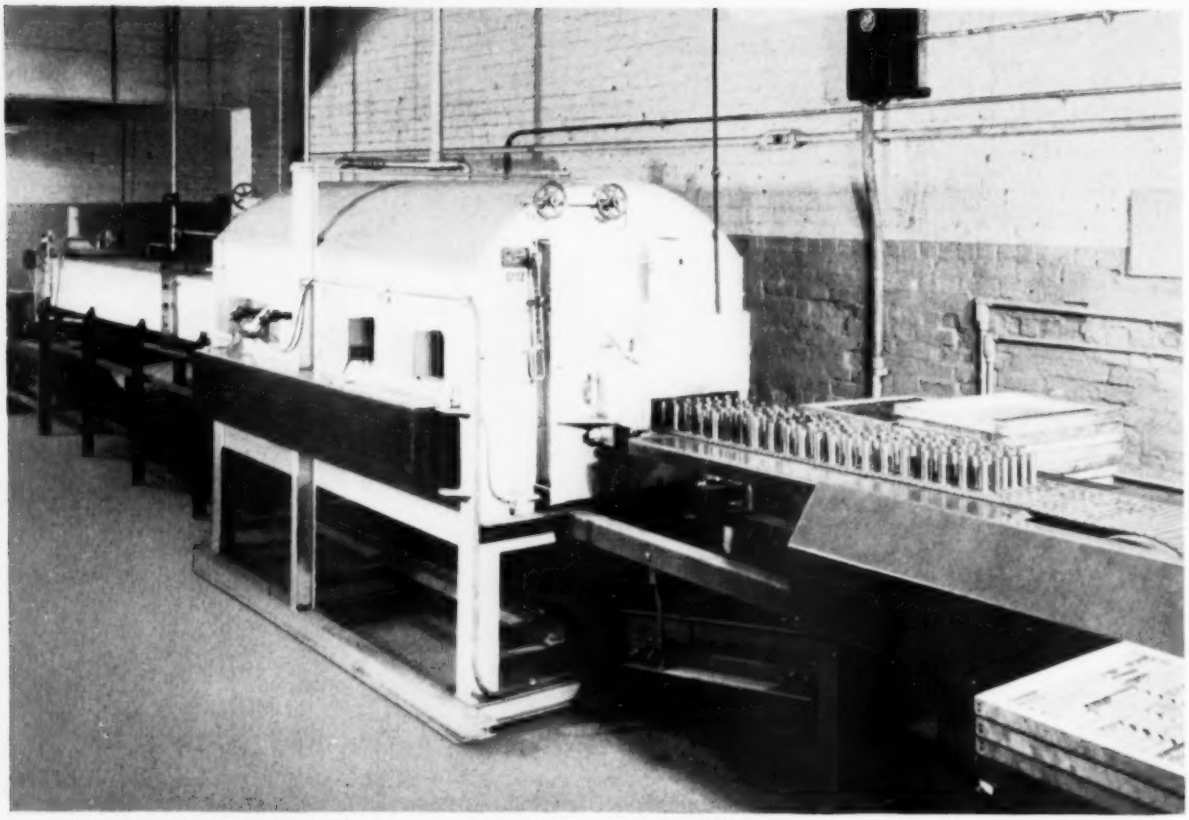

**USED FOR COPPER BRAZING** of hardware parts, this electric furnace was built by American Electric Furnace Inc., Boston, Mass. for Sargent & Company, well known hardware manufacturers of New Haven, Conn. The alloy conveyor belt at right runs over Norton CRYSTOLON* hearth tile in the furnace.

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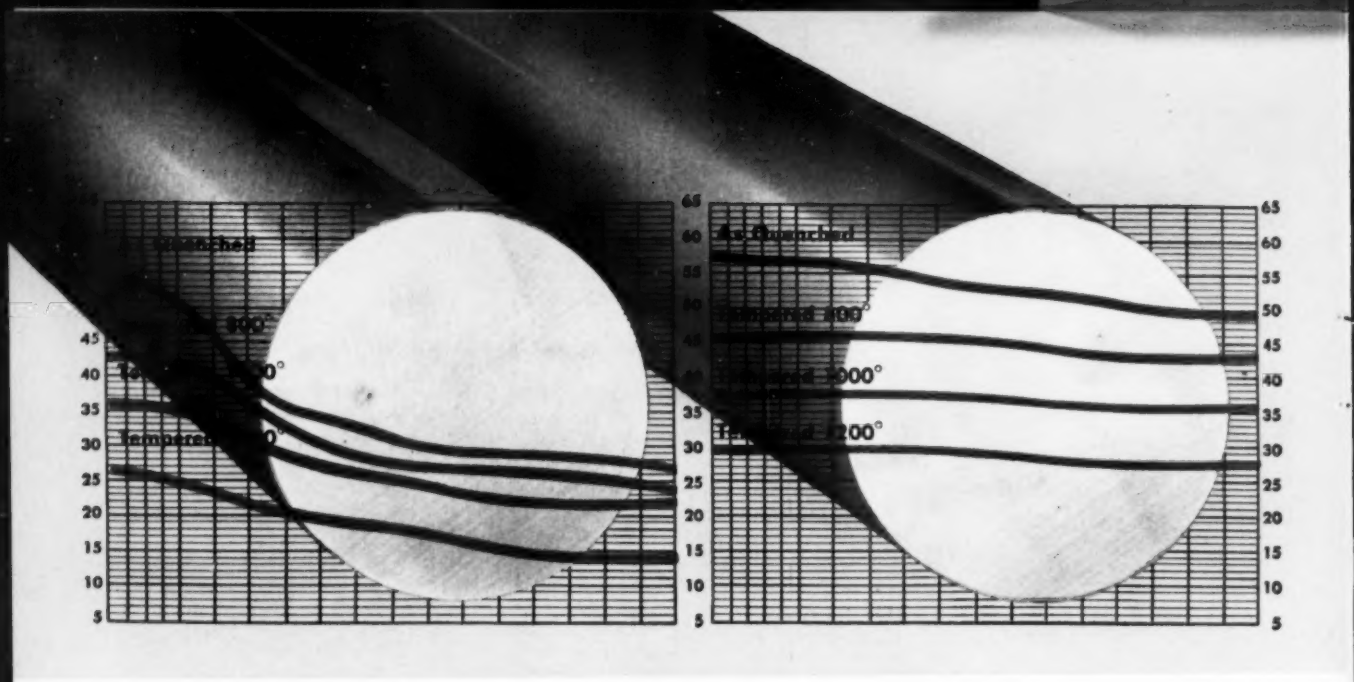


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# Critical Points

by the Editor

## Radar Manufacture

WHILE AT Winston-Salem, visiting with The Carolinas Chapter, ⊕, embraced an opportunity to inspect Western Electric's manufacturing operations in that city. In contrast to Western Electric's massive new plant in Indianapolis for manufacturing telephone receivers, briefly described in "Critical Points" in January 1951, the company's activities in North Carolina are scattered in three communities, Winston-Salem, Greensboro and Burlington, wherever suitable empty buildings could be found to absorb a rapidly expanding department. In this region are manufactured not only the equipment necessary to transmit voice and video from tower to tower (through the air rather than by buried coaxial cable), but also the anti-aircraft radar equipment, both mobile and fixed, which will find and track the enemy and point the guns, and the electronic equipment for fighters and bombers which will "home" to the objective and release the bombs at the correct instant. In airborne equipment space and weight are paramount, and it was wonderful to see a germanium transistor encased in a blob of plastic no bigger than a shriveled pea, yet doing much the same thing as a common tube in a radio set. Then there are special devices almost without number for the Navy to spot targets and lay the guns.

My guide, Albert R. Fairchild, metallurgical engineer for Western Electric and chairman of The Carolinas Chapter, said that many of the tiny parts used in the assemblies are made by the clock and jewelry trades, which have the necessary skill and equipment. Jewelry, however, is seldom made to the dimensional tolerances required; also the jargon or terminology is unique, so some amusing and even exasperating interchanges have occurred before metallurgist and jewelry maker could understand each other's language.

Wave guides, so-called, were especially interesting to the Editor. They are extruded thin-walled tubes of copper, square in cross section. Their function is to transmit electrical impulses from receivers to amplifiers, or from amplifiers to transmitters; apparently these impulses travel inside these evacuated tubes. Some of the wave guides for broadcasting towers are straight, perhaps 20 ft. long, and $1\frac{1}{4} \times 2\frac{1}{4}$ in. inside dimension. The more interesting ones for mobile radar equipment are shorter and smaller, say $\frac{3}{8} \times 1$ in., and may be bent until they are crooked as a dog's hind leg to thread their way through a compact assembly of computing or other electrical equipment. But here's the catch: The inner small dimension may not vary (after bending) by as much as 0.003 in. Sharp bends in square tubing without wrinkles or upset walls are not easy to make – the conventional method of packing with sand or a tight-fitting spring is not good enough. An "integrated" mandrel – perhaps "articulated" would be a better word – is used instead. This consists of a number of curved links, pinned together, which are inserted in the straight tube, and when the tube is bent the linkage also moves so its outer surface sweeps the exact radius required for the inside dimension. Process anneal is required after such an operation, but only after meticulous cleaning wherein the final rinse must be in a freshly distilled solvent else a trace of lubricant will carbonize and roughen the inner surface enough to drag upon the electrical waves. Final inspection is just that – waves of known shape and frequency are transmitted, and if any measurable distortion occurs (from any cause) the item is rejected.

## Trends in Induction Heating

ATTENDED a party for engineering editors celebrating the opening of Tocco's fine manufacturing and development building in Cleveland and bethought myself of my first visit with Bill Benninghoff, ⊕, the genial general manager. It was in the mid-thirties, and he had just been hired by W. C. Dunn, president of Ohio Crankshaft Co., to perfect the new use of induced high-frequency currents to heat crankshaft bearings for hardening. He had a rudimentary device set up in the forge shop; that was the whole department. The deserved success of this method of differential or surface hardening is universally known; what may be news is that most of the new equipment now being built is not for surface hardening but is intended for other uses of induction heat such as for through hardening, tempering or annealing, for heating forging stock (ferrous and nonferrous), for brazing, and soldering. A most important recent application to reach commer-

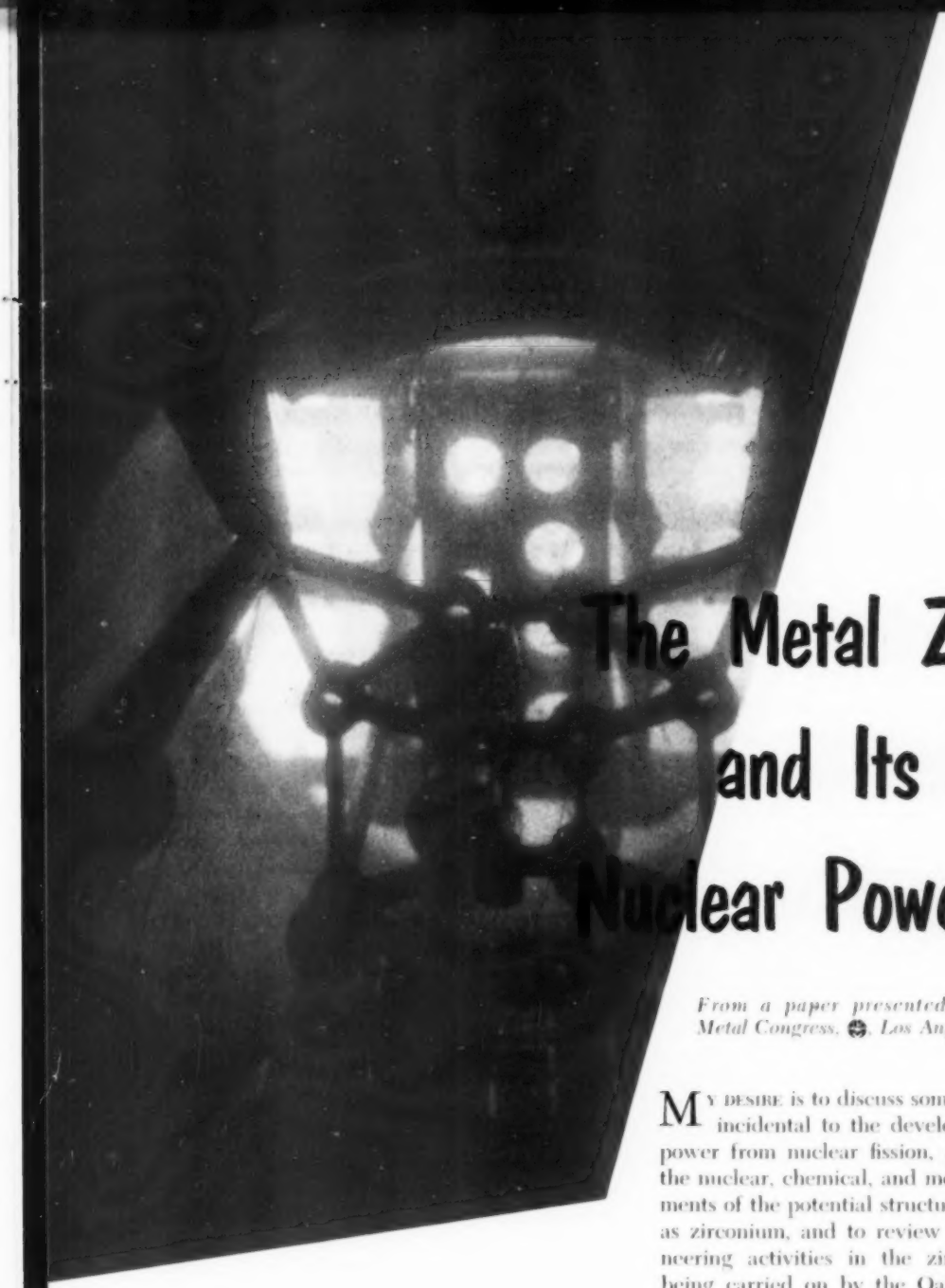
cial use is the induction heating of abutting surfaces to a plastic condition and pressing them together – a modernization of the ancient forge-welding technique. A plant on the Pacific Coast is to use this idea to make butt-welded pipe from bent strip or plate.

About one sixth the floor area of the Tocco building and 10% of the employees are devoted to development and industrial research. Many conventional applications require study to determine the best combination of voltage and current frequency, and to devise proper inductors, quenching devices, and handling fixtures that will prove most suitable for the intended volume of production.

A matter of equal or greater importance discussed by Harry Osborn, ⓐ, technical director, is the study of applications of future importance – things which may loom large in future business. Among these are high-frequency heating to maintain the temperature of metal being continuously cast (if the stream is too hot, also, the water-cooled inductors can act as coolers), the heating of strip in the mill, either between roll stands in continuous mills or for annealing finished strip, ferrous or nonferrous. A new adaptation of the induction heater for forging stock is the heating of long bars as they go through high-speed continuous forging machines. Internal hardening of cylinder bores in automotive engine blocks cast of low-alloy, machinable iron may replace more expensive steel liners in bus and truck engines. Design of efficient electrical equipment is also most important and is leading the research staff into those intriguing frequencies in the ultrasonic range, even now used for such diverse things as submarine radar, scale breakers and testing for subsurface defects.

## Note on Beryllium Poisoning

In *Metal Progress* for December 1952, an article describing the extrusion, forging and welding of beryllium metal was followed by a warning about beryllium poisoning, a warning intended to apply to operations on commercially pure metal or its high alloys. As always, this resulted in anxious inquiries concerning the fabrication of copper hardened with 2% beryllium, a widely used industrial alloy. While no complete agreement exists among investigators of toxicity of beryllium and its compounds, it may be stated that almost all cases of beryllium poisoning have arisen in or near plants reducing metal from its ores or making and using beryllium phosphors for fluorescent lamps. Some cases have occurred in workmen melting and formulating the so-called master alloys which have contained considerably more than 2% beryllium, but the Editor is assured by leading medical investigators that no cases have yet been identified with exposure to alloys containing 2% or less of beryllium in their ordinary shop fabrication, such as machining, heat treating, or other hot and cold working. However, since fine beryllium dust or beryllium oxide is hazardous to certain susceptible individuals in exceedingly small concentrations, it is only the part of caution to perform such operations as dry grinding or shearing and welding of beryllium-copper alloys in equipment where dust and smoke are immediately swept away by adequate exhausts and vented outside. Grinders and welders should also wear respirators. To be on the safe side, beryllium-copper scrap should be segregated, excluded from ordinary foundry mixes, and returned to the manufacturer of the alloy.



# The Metal Zirconium and Its Place in Nuclear Power Plants

*From a paper presented to the Western Metal Congress, Los Angeles, March 1953.*

MY DESIRE is to discuss some of the problems incidental to the development of atomic power from nuclear fission, particularly as to the nuclear, chemical, and mechanical requirements of the potential structural materials such as zirconium, and to review some of the pioneering activities in the zirconium program being carried on by the Oak Ridge National Laboratory and the Electromagnetic Production Facility, both of which are operated for the Atomic Energy Commission by the Carbide and Carbon Chemicals Co.

This paper will be fundamentally influenced by security regulations. Scientific information on metals lighter than lead is usually "declassified", but declassification is either expressly forbidden or strictly limited on several aspects

By EDWARD C. MILLER, Metallurgy Division, Oak Ridge, Tenn., National Laboratory
(Operated by Carbide & Carbon Chemicals Co.
for the Atomic Energy Commission)

of zirconium refining and utilization. Therefore, much of this paper is derived from already declassified or "open" material; some essential data must be omitted; in some instances, the reader may have to substitute inferences for conclusions. (There is, of course, no assurance that the inferences will be either obvious or correct.)

So, having offered the appropriate apologies, let me proceed to a few pertinent and perhaps reasonably well-known facts.

There are several actual and potential functions of nuclear reactors. First is the production of fissionable material for atomic weapons. It has been reported that they may produce the essential material to be used in the newer thermo-nuclear weapons. Reactors produce radioactive isotopes and fission products, and these decay to give other isotopes, alpha particles, neutrons, and beta and gamma rays, which have actual or potential applications in medicine, industry, agriculture, and research. Finally, reactors produce enormous quantities of heat, and the conversion of the heat to useful power is a major challenge to engineers and scientists in and out of the nuclear energy business.

Two isotopes of uranium ($U^{235}$ and $U^{233}$) and one of plutonium ($Pu^{239}$) are, it is assumed, capable of supporting a chain reaction in a nuclear reactor and are thus potential nuclear fuels. Of these, only $U^{235}$ occurs in nature; it represents about 0.7% of natural uranium, and, except for about 0.005% $U^{234}$, the remainder of natural uranium metal is the $U^{238}$ isotope. Much of the wartime work at Oak Ridge concerned separation of $U^{235}$ from $U^{238}$.

Fortunately, the other two fissionable isotopes can be produced from thorium and uranium according to the reactions:*

$$92U^{238} + 0n^{1} \rightarrow \underset{23\ Min.}{92U^{239}}\ \beta^{-} \rightarrow \underset{2.3\ Days}{93Np^{239}}\ \beta^{-} \rightarrow 94Pu^{239}$$

$$90Th^{232} + 0n^{1} \rightarrow \underset{23.5\ Min.}{90Th^{233}}\ \beta^{-} \rightarrow \underset{27.3\ Days}{91Pa^{233}}\ \beta^{-} \rightarrow 92U^{233}$$

*Editor's Note – Translated, the first reaction states that the relatively stable 238 isotope of uranium captures a neutron (usually originating during the fission of $U^{235}$), forming the quite unstable 239 isotope with half-life of 23 min. and which radiates a negatively charged beta particle (electron) transforming it into the next heavier element, neptunium, No. 93. Neptunium is also very unstable, with half-life of 2.3 days; it also ejects an electron and transforms into the plutonium, a relatively stable metal as long as it is not attacked by a neutron.

In most operating and contemplated reactors, the neutrons produced by fission exceed the neutrons absorbed *(a)* in continuing the chain reaction plus *(b)* the neutrons lost by leakage from the reactor plus *(c)* the neutrons captured parasitically by fuel, coolant, moderator, reflector, transmuted elements, fission products, and structural materials. Under appropriate conditions, this neutron excess can be used to generate more fissionable material by the reactions indicated above. This possibility of regenerating the fissionable isotope fuel, getting more out at the end than we put in – which at first glance seems to be perpetual motion – suggests several significant and intriguing questions, three of which we shall consider next:

First, if we assume that most of the potential fuel energy of the fertile $U^{238}$ and $Th^{232}$ can actually be made available, what contribution might this make to the world's energy supplies?

Second, can all or most of the available $Th^{232}$ and $U^{238}$ in the metal as it occurs in nature be converted to reactor fuel?

Third, what additional technological problems are created by this possibility of regeneration of fissionable material, and in what ways may we hope they can be solved?

Thus, we shall consider the factors of motivation, feasibility, and technology. A fourth significant factor, economics, may well be the ultimately determining one, but it can be discussed here only in the most general terms.

## URANIUM AS AN ENERGY SOURCE

Estimation of the potential life of geological reserves of fuels like coal, petroleum, uranium, or thorium is at best uncertain, because it projects several broad assumptions, for decades and even centuries, such as the rate of consumption, economical recoveries, growth of reserves through prospecting, and efficiency of utilization. Nevertheless, some interesting estimates are available from a survey made by Palmer Putnam, a consultant to the Atomic Energy Commission, who adopts a symbol Q to represent $10^{18}$ B.t.u.:

| | |
|---|---|
| World energy burn-up, 1 A.D. to 1860 | 6 to 9.0Q |
| 1860 to 1947 | 4.0Q |
| 1947 | 0.1Q |
| Estimated possible burn-up, 1950-2000 | 20 Q |
| All available U. S. coal reserves | 68.0Q |
| Economically recoverable U. S. coal | 6.0Q |
| Economically recoverable world coal reserves | 30 Q |
| Economically recoverable world oil reserves | 6 Q |

On the basis of these figures we will exhaust the "economically recoverable" coal and petroleum within the foreseeable future.

In considering the possible contribution of uranium to these power reserves, Lawrence R. Hafstad, director of A.E.C.'s reactor developments, states that "assuming . . . all available uranium can be used, Putnam's study comes up with a guess – and he does not claim it to be any more than a guess – of at least 100Q for the economically recoverable reserves of uranium. This would last the world many decades and would probably give time to develop the art of using continuous solar energy, as Conant has recently pointed out we must ultimately learn to do."

Therefore, if we assume a continuing increase in the world's energy demands, new energy sources will be required. If a substantial part of the recoverable $U^{238}$ and $Th^{232}$ can be converted to fuel and utilized economically, nuclear fission may well supply a significant part of this demand. But, if $U^{235}$ should be the only economically available nuclear fuel, and if we assume Mr. Putnam's 100Q guess for uranium (only 0.7% of which is $U^{235}$) to be a reasonable approximation, nuclear power is likely to be confined to some specialized applications for which it is so well suited, such as mobile military power units and stationary power generation in geographically inaccessible regions. Actually, these specialized applications are by no means small. They would be comparable to steam-turbine units aboard naval and merchant vessels, and to central stations in isolated areas.

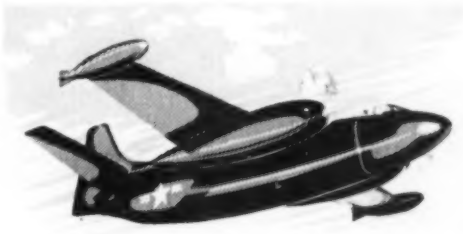
### FEASIBILITY OF ATOMIC POWER

Most of the ensuing discussion of feasibility of converting $U^{238}$ and $Th^{232}$ to fissionable material will be arbitrarily limited to the production and use of $Pu^{239}$ in *thermal* reactors, but it should not be inferred that thorium or *fast* reactors are unimportant.

The understanding of a few physical principles novel to old-school metallurgists and the explanation of a few terms are in order before the engineering of reactors can be discussed.

*Fissionable material* may be defined for our purposes as atoms which absorb neutrons and split in two with the liberation of more neutrons. *Fertile material* consists of atoms which absorb neutrons and are thereby converted into fissionable material. The conversion of fertile material to fissionable material in a reactor is called *regeneration*. The term *regenerative efficiency* expresses the ratio of the number of fissionable atoms produced to the number of such atoms consumed. If this ratio is greater than one, we apply the term *breeding* to the process, and we speak of *breeding gain* as the ratio of excess atoms of fissionable material produced to fissionable atoms consumed.

The *nuclear cross section* is a measure of the probability that a colliding particle will cause a nuclear reaction;* it is represented by $\sigma$, the Greek letter sigma. If merely the number of particles absorbed by atoms of the target are under consideration the "absorption cross section" is denoted by $\sigma_a$. Absorption may result in fission; the fission cross section is symbolized by $\sigma_f$. All such values used later in this paper are for thermal neutrons moving at the speed of atoms in matter at ordinary temperatures, namely 5000 mi. per hr., having an energy of about 0.025 electron volt.†



The regenerative efficiencies of most reactors are classified data; however, a value of 0.8 has been published for "CP-3", the research reactor at Argonne National Laboratory utilizing natural uranium and moderated with heavy water. Now, if we neglect the obvious necessity of maintaining not less than the critical mass of fissionable material, and assume, among other things, that a hypothetical reactor starts with natural uranium (containing 0.7% fissionable isotope $U^{235}$) and regenerates at the rate of 0.8 until all the original $U^{235}$ and the regenerated fuel are used up, then the fraction

*Editor's Footnote – $\sigma = A/NI$ where A is the number of nuclei which undergo transformation in unit time, N is the number of atoms per sq.cm. in the target, and I is the number of incident particles. Many experimental values are in the neighborhood of $10^{-24}$ sq.cm. per nucleus, and this value has been dubbed 1 barn.

†Fast electrons liberated when an atom splits have initial speeds averaging 5% the speed of light and energies of about 1,000,000 electron volts.

of the original uranium that is ultimately consumed will equal 3.5%, which is the sum of the infinite geometric progressions:

$$0.007 + (0.007 \times 0.8) + (0.007 \times 0.8^2) + (0.007 \times 0.8^3) + \ldots = \frac{0.007}{1 - 0.8} = 0.035$$

Similarly, if we substitute several other regenerative efficiencies in this progression, we obtain the curve of Fig. 1. This curve is significant, not for its precision (which it obviously lacks), but because it indicates the substantial premium that results from relatively small increases in regenerative efficiency – particularly as this approaches unity.

Estimation of the *attainable* regenerative efficiency of a reactor requires even more tenuous approximations. Let us consider a reactor system involving only thermal neutrons, fertile $U^{238}$, and fissionable $Pu^{239}$. The available declassified data tell us that from 2.9 to 3.1 neutrons are emitted from each atom of $Pu^{239}$ which splits. Not all the plutonium atoms that absorb neutrons actually fission; the absorption cross section $\sigma_a$ is 361 barns and the fission cross section $\sigma_f$ is 664 barns, so, for each neutron consumed in $Pu^{239}$, the net number of neutrons produced is only

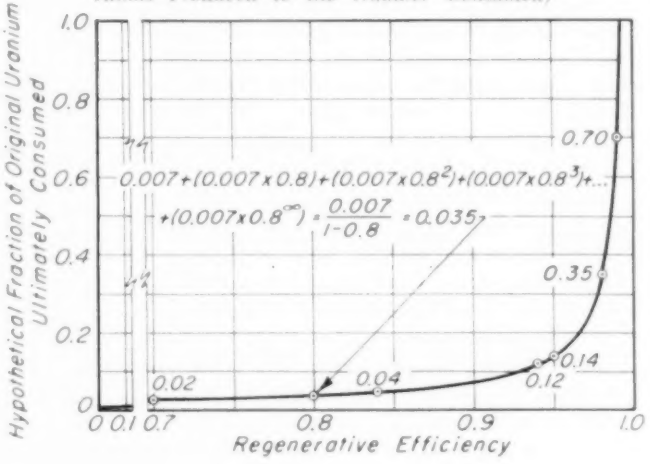
$$3.0 \frac{\sigma_f}{\sigma_f + \sigma_a} = 3.0 \times \frac{664}{664 + 361} = 1.95.$$

Since one neutron is required to continue the chain reaction, the maximum theoretical regenerative efficiency is 0.95. However, in even the best-moderated chain reactor all fission neutrons are fast at the instant of generation, and some small part of these may improve the regenerative efficiency if they can be absorbed by $U^{238}$ and cause this atom to disintegrate. On the other hand, the regenerative efficiency of a thermal reactor will be reduced by *(a)* leakage of neutrons from the reactor, *(b)* parasitic capture of neutrons by fuel, coolant, moderator, reflector, transmuted elements, fission products, and structural materials, and *(c)* loss of delayed neutrons and of fuel atoms due to less than 100% recovery during refining or chemical processing to remove regenerated fuel and minimize capture.

**Influence of Structural Materials on Efficiency of the Power Unit** – Metallurgists are most likely to be primarily concerned with the effect of parasitic capture of neutrons by different structural materials. Again, let us postulate a fictitious thermal reactor regenerating and re-using plutonium and producing for each 100 atoms fissioned an excess of 95 neutrons as computed above, of which 10 are lost in leakage from the reactor or by parasitic absorption in other than structural materials. Now, we will arbitrarily assume, in one case, that this reactor contains a structural material of low cross section, such as aluminum or zirconium with $\sigma_a$ of about 0.2 barn, which will absorb one of the remaining 85 neutrons – and in another case we assume a more absorbent material such as an 18-8 stainless steel with an absorption cross section $\sigma_a$ of about 3 barns which absorbs 15 of these neutrons. This would leave a net regenerative efficiency for the low cross-section material of 0.84, and, for the higher cross section, of 0.70.

Interpreting these efficiencies by the aid of Fig. 1 – always with appropriate qualifications – it can be seen that we might hope to use up 4.4% of the uranium if the structural material were zirconium, but only 2.3% of it if the structural material had a relatively high cross section. If we disregard the 10 neutrons lost due to leakage and parasitic capture other than by structural elements, we will have regenerative efficiencies of 0.94 and 0.80 and fuel utilizations of 12% and 3.5%, respectively. It is quite evident that the fuel utilization will

*Fig. 1 – Maximum Fraction of Original Uranium Which Could Be Theoretically Consumed, Assuming Various Values for Regenerative Efficiency (Ratio of Number of Fissionable Atoms Produced to the Number Consumed)*



be quite dependent on the cross section of the structural material.

If we concede a prominent role to thermal reactors in the long-range nuclear power program, structural materials of low cross section may well be the most significant economic factor. Even in the operating reactors that produce various isotopes, including fissionable ones, the efficiency of conversion depends in considerable part upon a low parasitic absorption of neutrons by structural materials.

There are other reasons for using materials of low cross section. Most important is that excessive parasitic absorption requires an increased investment in fuel and, possibly, enrichment in the fissionable isotope to above the amount contained in natural uranium to attain criticality or a given power level. Neutrons, parasitically absorbed, also generally form radioactive isotopes and transmuted elements, and the radiations thus developed can create difficult problems in shielding – or in handling and repair if such operations make it necessary to remove the structural components from the reactor.

## AUXILIARY REQUIREMENTS

Nuclear reactors and their associated equipment place other severe and frequently unique requirements on structural materials which vary with the type of reactor. There are also variations between individual components of a single reactor system. These demands will now be indicated in general terms without regard to specific reactors, and within the extent of the published unclassified literature. They have been listed in a picturesque statement, credited to W. E. Kelley, until recently manager of the New York Operations Office of the Atomic Energy Commission:

"We need designs of pumps that work at higher pressures – that will handle corrosive gases and fluids with little maintenance. We need piping that won't leak; valves that are so tight that a few stray molecules will have trouble getting by. We need designs of equipment that will turn faster than the velocity of sound at extremes of high and low temperatures. We need construction materials that will be safe and strong at —450° F. and some at +4000° F. We need equipment so simple that it can be operated and maintained from behind a 10-ft. wall. We may also specify that, because of special nuclear requirements, the structural material for one of these gadgets must be selected from three or four elements of nature, none of which has ever been used as a structural material before!"

In more detailed form, the requirements placed on structural materials and equipment in a power reactor system include:

1. Thermal stability under the severe stresses resulting from high rates of heat generation and removal.
2. Leakproof, corrosion resistant, reliable performance in the presence of corrosive, high-velocity, radioactive coolants at high temperatures and pressures.
3. Adaptability to maintenance and repair by remote handling equipment.
4. Low cross sections for neutron absorption.
5. Avoidance of formation of high-activity isotopes in removable components in order to minimize shielding problems during handling.
6. Resistance to mechanical damage resulting from bombardment by neutrons.

**Metals With Low Absorption Characteristics** – We are not at liberty to discuss in any detail the suitability of a specific material for a specific application; however, we can obtain a general comparison of materials by an arbitrary tabulation on the basis of properties known to have significance. Tables I and II are adapted from similar tables in an unclassified paper by G. E. Evans.

The more commonly available elements are listed in Table I in order of increasing absorptions of thermal neutrons and are further divided into groups of low, medium, and high cross section. Melting points have been included for the metallic elements in the first two categories.

Of the possible constructional materials set in bold-face type, beryllium is reported to be expensive, brittle, and chemically active. Aluminum, magnesium, and their alloys have good strength at ordinary temperatures and should have excellent possibilities for reactor use where the chemical environments and temperatures permit. Zirconium retains strength to moderately high temperatures, and it has good corrosion resistance in some environments.

If we are permitted a somewhat higher cross section, the metals printed in bold face in the second column of Table I assume importance, and some are components of common high-temperature alloys. Again, by adapting Evans' classification, we obtain Table II, which lists some of the better-known "refractory" metals and alloys which, on the basis of information available in the open literature, appear to be

more promising for reactor use. This table, more graphically than anything I can say, indicates the reason for our interest in zirconium.

To avoid creating an incorrect impression it should be pointed out that other alternatives exist – at least in theory. Our discussion has so far been postulated on the use of a chain reaction of the type used in the A.E.C. reactors – namely, originating and continuing by virtue of neutrons liberated during the fission of atoms of uranium. Neutrons can be obtained from other sources. Whether they can be utilized for power production is another matter, but assuming that they can, these neutrons could most logically augment those obtained by fission of the initial 0.7% $U^{235}$ in a more or less conventional reactor and would thereafter be successively multiplied by regeneration of fissionable material from fertile material. Probably any such source of neutrons would be expensive in terms of consumption of scarce materials or other forms of energy, and we would still have to maintain the strictest neutron economy in order to insure maximum multiplication of available neutrons during the regenerative process.

Another alternative is the use of breeding reactors operating on neutrons in the fast or intermediate energy range. With certain exceptions, fast neutrons are less susceptible to capture than thermal neutrons – that is, the cross sections of most materials are much less in the high-energy range than in the thermal range. Also, there is less spread in the fast-neutron cross sections of different materials. Fast and intermediate reactors may exceed 100% regenerative efficiency, which would make true breeders of them, and a greater variety of structural materials could be used in them without the penalty of excessive neutron losses.

On the other hand, fast reactors – because of their generally lower capture cross sections – require a greater fuel investment to achieve a given power rating and a higher concentration of fissionable isotope in the reactor; they are not susceptible to effective control by absorbers (control rods) as are thermal reactors; removal of generated heat involves serious problems; and the potential radiation damage to structural materials is greater because of the more intense neutron bombardment. A plutonium breeding cycle will probably require a fast or an intermediate reactor – at least as part of the cycle. The problem probably cannot be solved until we accumulate experience with these different reactor types and learn their practical advantages and limitations.

C. G. Suits of General Electric Co. has stated that "The high-temperature power-breeder reactor which would utilize substantially all the heat and all of the fuel, must be regarded as

**Table I – Cross Sections of Commonly Available Elements**

| Low Cross Section (Less Than 1.0 Barn) | | | Intermediate Cross Section (1.0 to 10.0 Barns) | | | High Cross Section (Greater Than 10 Barns) | |
|---|---|---|---|---|---|---|---|
| Element* | $\sigma_a$ | Melting Point | Element* | $\sigma_a$ | Melting Point | Element | $\sigma_a$ |
| Oxygen | 0.0002 | | Zinc | 1.1 | 419° C. | Manganese | 13 |
| **Carbon** | 0.0045 | | **Columbium** | 1.1 | 2415 | Tungsten | 19 |
| **Beryllium** | 0.009 | 1280° C. | Barium | 1.2 | 704 | Tantalum | 21 |
| Fluorine | 0.01 | | Strontium | 1.2 | 770 | Chlorine | 32 |
| Bismuth | 0.032 | 271 | Nitrogen | 1.8 | | Cobalt | 35 |
| **Magnesium** | 0.059 | 651 | Potassium | 2.0 | 64 | Silver | 60 |
| Silicon | 0.13 | | Germanium | 2.3 | | Lithium | 67 |
| Phosphorus | 0.19 | | **Iron** | 2.4 | 1539 | Gold | 94 |
| **Zirconium** | 0.18 | 1845 | **Molybdenum** | 2.4 | 2625 | Hafnium | 115 |
| Lead | 0.17 | 327 | Gallium | 2.7 | 30 | Mercury | 380 |
| **Aluminum** | 0.22 | 660 | **Chromium** | 2.9 | 1890 | Iridium | 440 |
| Hydrogen | 0.33 | | Thallium | 3.3 | 300 | Boron | 750 |
| Calcium | 0.43 | 850 | **Copper** | 3.6 | 1083 | Cadmium | 2,400 |
| Sodium | 0.49 | 98 | **Nickel** | 4.5 | 1455 | Samarium | 6,500 |
| Sulphur | 0.49 | | Tellurium | 4.5 | | Gadolinium | 44,000 |
| Tin | 0.65 | 232 | **Vanadium** | 4.7 | 1710 | | |
| | | | Antimony | 6.4 | 630 | | |
| | | | **Titanium** | 5.6 | 1725 | | |

*Possible constructional metals in black face type.

**Table II – Selected Refractory Metals and Alloys**

| Low Cross Section (Less Than 1.0 Barn) | | Intermediate Cross Section (1.0 to 10.0 Barns) | |
|---|---|---|---|
| Metal | $\sigma_a$ | Metal | $\sigma_a$ |
| Zirconium | 0.18 | Iron | 2.4 |
| | | Molybdenum | 2.4 |
| | | Stainless steels | about 3 |
| | | Nickel-base alloys* | about 4 |
| | | Titanium | 5.6 |

*Hastelloys, Monels, Inconels, Nichrome.

the logical objective and challenge of the atomic industry in the years immediately ahead. Although the technological problems of building a power-breeder are formidable, they must be solved if we are to compete successfully in a plutonium economy."

Assuming the successful development of such a device, there still appears to be a substantial field for thermal reactors. Other authorities, such as J. Cockcroft and Samuel Glasstone, have suggested that the development of the nuclear power industry will require more than one distinct reactor type.

### AN ATOMIC POWER INDUSTRY

It appears reasonable to assume that the future large-scale utilization of nuclear power may very well involve three reactor types:

1. Fast or intermediate centralized breeders, designed to accomplish the maximum production of fissionable material, but also making full use of the thermal energy produced.

2. Enriched thermal reactors for specialized applications such as mobile power which is dependent, to a considerable extent, upon military requirements.

3. Natural uranium thermal reactors intended primarily for the economical production of useful power, and also designed to accomplish the maximum fuel regeneration consistent with efficient power production. As the fissionable material of such a reactor becomes depleted, it can be replenished by the addition of enriched material obtained from the central breeder reactors, No. 1 above.

The successful development of a substantial nuclear power industry does not depend on any one factor, but rather on the successful solution of several problems. Among the most important of these is the development of high-temperature metals and alloys of low cross section for structural use. The extent to which zirconium may contribute to this solution will depend in large measure upon research of the type being presented in the ⚙ symposium at the Western Metal Congress in March.

Now, may I conclude this presentation with a brief mention of some of the zirconium work at Oak Ridge.

## Zirconium Investigations at Oak Ridge

First was the recognition of the nuclear properties that make zirconium so attractive. Previous to about 1947 the generally accepted value given for the thermal-neutron cross section of zirconium was about 3.5 barns. On the basis of research conducted at the Oak Ridge National Laboratory during the winter of 1947, Pomerance, Feldman, and others reported a value of about 0.18 barn and established that the discrepancy was due to the 2 to 3% hafnium, which normally occurs in natural zirconium. The cross section of hafnium is currently listed as about 115 barns.

Utilization of zirconium in reactors therefore required the removal of substantially all the hafnium. Of all the chemical elements, zirconium and hafnium are probably the two most nearly alike in their chemical behavior; it is nearly as difficult to separate them chemically as it is to separate the isotopes of a single element, and concentrated research effort toward a practicable method of separating was begun at several locations in 1948. The Oak Ridge National Laboratory's Materials Chemistry Division, located in the Y-12 Area and consisting of a group of men who specialized in the chemistry of isotopic separations,* was successful and had a pilot plant in operation in September 1949 that produced several pounds of low-hafnium zirconium per day. Further research and modification of the pilot plant operation improved the yield and purity and lowered the cost. At the beginning of this work, hafnium-free, crystal-bar zirconium was available only in special production lots at a cost of about $1000 per lb., whereas commercial zirconium containing hafnium cost something less than $300 per lb. At present, the separated, hafnium-free zirconium oxide can be produced for well under $5 per lb. (To

*Editor's Footnote – This group had started with an intent study of the possibility that the uranium isotopes might be separated by chemical means. A summary of their conclusions about the requirements for a commercial process to separate isotopes cleanly is given by G. H. Clewett in Vol. I (1952) of the Annual Review of Nuclear Science, in a paper entitled "Chemical Separation of Stable Isotopes".

## Separation of Pure Zirconium

this must be added the cost of converting it to zirconium metal.)

This essential work was under the direction of G. H. Clewett, director of the Materials Chemistry Division, in cooperation with W. R. Grimes and W. M. Leaders, who were in charge of the laboratory chemical research and pilot plant programs, respectively.

Certain data pertaining to the actual separation method are still "classified" and therefore cannot be described in this paper. As a first step, practically all the hafnium is removed (normally to below 50 parts per million or 0.005%) from the commercial metal, dissolved in appropriate solution, and the zirconium chlorinated to $ZrCl_4$ solution. Next this solution is purified to less than 50 parts per million of each such elements as Al, Ca, Cu, Pb, Fe, Si, Mg, or Mn, even though the feed material contains several hundred parts per million of the impurity (or even a few tenths per cent in the case of iron).

However, the process does not remove phosphorus nor alkali metals that may be present. At first this purification consisted of adding salicylic acid to the aqueous $ZrCl_4$ feed, precipitating zirconium salicylate and leaving the impurities in solution. Next steps were filtration, washing and roasting the filter cake to a pure zirconium oxide $ZrO_2$.

Early work did not include extensive studies of the chlorination step, since other installations, such as the Albany, Ore., Station of the U. S. Bureau of Mines, were equipped to perform this research.

In January of 1950, the requirements for zirconium and the development of the process were such that it was decided to expand the pilot plant into a full-scale production unit, an expansion which was carried out by the chemical operations department and the engineering and maintenance division of the Electromagnetic Plant at Oak Ridge.

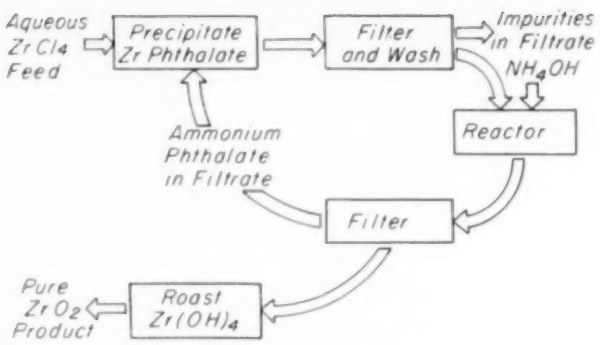



*Fig. 2 – Method of Purifying Low-Hafnium Zirconium Whereby the Principal Reagent Can Be Recycled*

After many tons of low-hafnium zirconium had been produced by this method, the process shown in Fig. 2 was introduced, which has the advantage that the precipitant, ammonium phthalate, can be recovered and recycled. This is accomplished by treating the zirconium phthalate precipitate with $NH_4OH$, which produces insoluble $Zr(OH)_4$ and a filtrate containing the phthalate that is suitable for recycling.

The present capacity of the plant is in excess of 1000 lb. per day. Incidentally, the plant is also capable of producing a hafnium product containing less than 2% zirconium.*

### APPLICATIONS

Occasional declassified articles in the technical press and the semi-annual reports of the U. S. Atomic Energy Commission have reported that in Oak Ridge we have or have had interest in several reactors such as the O.R.N.L. (or Clinton) graphite reactor, the M.T.R. or materials testing reactor (now operated by Phillips Petroleum Co. at Arco, Idaho), the L.I.T.R. or low-intensity test reactor at Oak Ridge [whose self-photograph occupies the front cover of this issue of *Metal Progress*] as well as the "swimming pool" or the bulk shielding facility, various aspects of aircraft nuclear propulsion reactors, a homogeneous reactor experiment, various advanced designs of homogeneous reactors, "package" power reactors, plus a surprising number of reactor designs on old envelopes that never got past the burn-basket. At any rate, we metallurgists at Oak Ridge have a substantial interest in reactors and all reactor materials – but as for zirconium, I can't tell you how, where, or whether it will be used in them!

*Editor's Footnote – Some additional successful but classified work in the metallurgy division of Oak Ridge National Laboratory has been done under direction of J. E. Cunningham. Metallurgical research is being conducted on the phase equilibria and phase interactions in alloys of zirconium, as a step in the design of alloys for specific reactor uses that have better mechanical properties and corrosion resistance than the pure metal. The unique feature of this study is the attempt to correlate alloying behavior with the electronic configuration of the atoms in the solid state. This work is being done by J. O. Betterton, with the cooperation of J. H. Frye, Jr., and L. K. Jetter.

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# Zr A Comparison of Zirconium With Better Known Commercial Metals*

A COMPARISON of zirconium with other metals allows predictions to be made by analogy, which can be of great value in the development of zirconium metallurgy. Zirconium is a "transition" element in the sense that it is characterized by an incomplete inner shell of *d* electrons, and has an allotropic transformation at 1590° F. (865° C.), transforming from a hexagonal crystal structure stable at lower temperatures to a body-centered cubic structure stable at higher temperatures. The primary effect of small alloying additions is to influence the characteristics of this transformation. Consequently, zirconium can best be compared with other "transition" metals possessing allotropic transformations, such as iron and titanium, and a few basic properties, such as alloying tendencies, effect of alloying on strength, and embrittlement phenomena, will be discussed in this paper.

## ALLOYING TENDENCIES

Zirconium, although a relatively refractory metal, melting at about 3350° F. or 1845° C., possesses comparatively poor tensile strength and creep resistance above 750° F. Since this temperature is within the recrystallization range, the only way to improve its creep resistance is by alloying. Alloy programs are extremely time consuming, and it would be desirable to utilize some method which would minimize a great deal of the experimental work. Accordingly, a discussion of the alloying tendencies of iron and titanium may serve to provide some formulation useful in the study of zirconium alloys.†

**Iron Alloys** – Formation of iron-base alloys has been found to follow certain regular trends. Iron has an allotropic transformation, transforming from a body-centered cubic structure to face-centered cubic as the temperature is raised through 1670° F. (910° C.). Consideration of dilute solutions of iron-base alloys allows us to establish certain empirical rules which aid in classifying binary-alloy additions. The most successful hypothesis has been the rule advanced by Wm. Hume-Rothery in his well-known "Atomic Theory for Students of Metallurgy". He postulated that if the interatomic distances of two elements differ by more than ±15 or 16%, their range of solid solubility would be very limited. If this "size factor" is favorable to the formation of solid solutions, other factors such as crystal structure, relative valency, and electrochemical characteristics, may restrict solid solubility. It has also been found that for *complete* solid solutions the interatomic distances of the two elements must not differ by more than 8% and their crystal structure must be the same.

It is a general observation that the elements to the *left* of iron in the periodic table (Fig. 1) tend to stabilize the alpha or low-temperature phase. In other words, the transformation temperature from α to γ is raised and the γ field

*From a contribution to the Symposium on Zirconium held at Western Metal Congress, Los Angeles, March 23, 1953. The complete transactions will shortly be published by the Society in book form.

†A lengthy unclassified "Discussion of the Factors Affecting the Constitution of Zirconium Alloys" has been prepared by P. C. L. Pfeil and issued but not published in June 1952 by the Atomic Energy Research Establishment, Harwell, Berks., England, as Document A.E.R.E. M/R 960.

is restricted. (Manganese is an exception to this observation, as it favors the formation of gamma.) On the other hand, elements to the *right* of iron tend to decrease the transformation temperature and stabilize the gamma phase. These include the elements Cu, Zn, and Au, which are considered to act to a limited extent as transition elements.

At least two reasons can be advanced for this behavior. The more obvious is that a certain crystal structure tends to stabilize the phase of similar structure. It is expected that elements possessing face-centered cubic structures would form extensive solid solutions in, and stabilize, the gamma phase of iron, also face-centered cubic. (However, this criterion becomes complicated when effects of other structures than cubic are considered.) The observation can also be made that the addition of elements of more *d* electrons in the unfilled *d* shell favors the formation of the gamma phase, while the addition of elements of a smaller number of *d* electrons tends to stabilize the alpha phase. The effects of the transition elements from the fourth and fifth periods are similar to those of the third period, and the outer *d* electrons have similar characteristics.

Usefulness of this electronic approach to alloying problems is demonstrated in the sections on titanium and zirconium later in this article, showing that predictions can be made about the effects of small amounts of solute elements. A reason for the justification of this criterion was advanced by M. F. Manning in an article in *Physical Review*, 1943, p. 190. He concluded that by increasing the number of electrons per atom, the "electron-energy band" will be enlarged, favoring the face-centered structure. The application of this criterion has been made in the present paper on the basis of observation and without the knowledge of electron-energy distribution curves. It is presented as an aid toward a systemization of the effects of alloying elements on the equilibrium diagrams.

The use of electronic considerations can be extended to the properties of the alloys at elevated temperature. According to Pauli's exclusion principle, there can be only two electrons in any one quantum level or orbit, and these must be of opposite rotation or spin. The *d* shell can contain 10 electrons, and it is considered that the first five electrons in the *d* orbit are unpaired in the sense that they have the same direction of spin. The free atom of iron with six *d* electrons contains one set of paired *d* electrons and four unpaired *d* electrons. Other elements with unpaired *d* electrons, such as molybdenum and chromium, and others containing five or less electrons in the *d* orbit would then combine with iron to form sets of paired electrons. Elements with paired electrons, such as nickel, cobalt and copper, and others containing seven or more electrons in the *d* orbit, although still forming solid solutions with iron, would be expected to produce a relatively small *d* shell interaction, and consequently result in less alpha-phase strengthening at elevated temperatures. It is interesting to note that the creep resistance of alpha iron at 800° F. is enhanced more by molybdenum, chromium and manganese than by nickel and cobalt. Another indication of the validity of electronic considerations is in the softening temperature after cold working; the important alloying elements in iron can be rated in the order of descending effectiveness as follows: molybdenum, manganese, chromium, cobalt, and nickel.

**Titanium Alloys** – Titanium, a transitional metal, has an outer free-electron configuration of $3d^2 4s^2$ and transforms from the beta body-centered cubic allotrope to the alpha close-packed hexagonal allotrope at 1620° F. (883° C.). The effects of solute atoms on its transformation characteristics can be systematized on the same basis as indicated above for iron. As *d* electrons are added to titanium, the beta or high-temperature phase is stabilized. This is usually manifested by an expansion of the

Zirconium, a transition element characterized by an incomplete inner shell of *d* electrons, is compared with two other important metals, iron and titanium. Zirconium, iron, and titanium possess allotropic transformations, and alloying elements affect these transformations. It is possible to predict, in an empirical way, the effects of minor alloy additions, and it appears that alloying of zirconium is similar to the alloying of titanium and iron. Zirconium is also notch brittle, similar to iron. Effect of alloying elements on strength at elevated temperature is also comparable with iron-base and titanium-base alloys.

beta field, a lowering of the transformation temperature, and the formation of a eutectoid. If an element of fewer *d* electrons is added to titanium, the converse is true; the beta phase is contracted, the transformation temperature is raised, and a peritectoid reaction occurs.

Thus, V, Cr, Mn, Fe, Co, Ni, Cu, Cb, Mo, Ta, and W, all containing more outer *d* electrons than titanium, tend to stabilize the beta phase. On the other hand, the elements of the Ia, IIa, IIIa, and IIIb, IVb, VIb groups, if the other conditions permit, would tend to form alloys favoring the alpha phase and peritectoids. Aluminum follows this trend, although silicon is an exception and lowers the transformation temperature, resulting in a eutectoid reaction.

The effects of carbon in iron are well known. Alpha iron, having smaller interstices than the gamma modification, rejects carbon, and a eutectoid system susceptible to heat treatment results. This forms the basis of most commercial alloys. In titanium the situation is reversed, and the high-temperature cubic modification has smaller interstices than the low-temperature hexagonal phase, and consequently the low-temperature phase is favored in alloys with carbon, and a peritectoid reaction occurs. This same relation holds for oxygen and nitrogen; both raise the transformation temperature in titanium and lower it in iron.

**Zirconium Alloys** – Zirconium, like titanium, has a $4d^2 5s^2$ outer free-electron configuration. Since both are in Group IVa of the periodic table, they might be expected to show similar alloying tendencies. From what is known of the binary zirconium alloys, this appears to be true, with exceptions based on the fact that zirconium has an interatomic distance which is approximately 8% larger than titanium, both in the alpha and beta modifications. Having in mind the 15% size factor rule, one will expect that several elements which are too large for titanium will be favorable for zirconium. Also, there will be elements too small for zirconium which will be favorable for titanium. Since zirconium has a rather large interatomic distance, fewer elements will be expected to alloy with zirconium than with titanium. As shown in Fig. 1, among the elements which are borderline (marked B) or unfavorable for zirconium (marked U) are the important transition elements Ni, Co, Fe, Mn, Cr, and V. The latter four elements are utilized in commercial alloys of titanium.

The relatively high melting point of zirconium makes it extremely doubtful whether commercial alloys could be made with elements which boil much below this temperature. This consideration tends to rule out As, Ba, Cd, Cs, Li, Mg, Hg, Se, Te, In, Bi, Sb, and Ce. This is not meant to imply that alloys of these elements *cannot* be made, but that their properties would have to be unique to warrant special fabrication techniques.

A rather arbitrary selection of possible metallic alloying elements for zirconium is shown in Fig. 2. The agreement is good between the outer *d* electron criterion and the measured phase-transformation shift, and there are apparently no exceptions among the known equilibrium diagrams. The effects of titanium and hafnium can be understood when it is remembered they are completely soluble in both the

*Fig. 1 – Periodic Arrangement of the Elements Showing Alloying Tendencies With Zirconium. Size factors are per cent difference of interatomic distance from that of zirconium (based on coordination number 12)*

| Period | Ia | IIa | IIIa | IVa | Va | VIa | VIIa | VIII | VIII | VIII | Ib | IIb | IIIb | IVb | Vb | VIb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Li −3 F $s^1$ | Be −29 U $s^2$ | | | | | | | | | | | B −39 U $s^2 p^1$ | C −43 U $s^2 p^2$ | N −44 U $s^2 p^3$ | O |
| 3 | Na +19 U $s^1$ | Mg +1 F $s^2$ | | | | | | | | | | | Al −10 F $s^2 p^1$ | Si −18 U $s^2 p^2$ | P −19 U $s^2 p^3$ | S −20 U $s^2 p^4$ |
| 4 | K +47 U $s^1$ | Ca +24 U $s^2$ | Sc +2 F $d^1 s^2$ | Ti −8 F $d^2 s^2$ | V −16 B $d^3 s^2$ | Cr −21 U $d^5 s^1$ | Mn −15 B $d^5 s^2$ | Fe −21 U $d^6 s^2$ | Co −22 U $d^7 s^2$ | Ni −22 U $d^8 s^2$ | Cu −20 U $d^{10} s^1$ | Zn −14 B $s^2$ | Ga −12 F $s^2 p^1$ | Ge −14 B $s^2 p^2$ | As −15 F $s^2 p^3$ | Se −12 F $s^2 p^4$ |
| 5 | Rb +55 U $s^1$ | Sr +35 U $s^2$ | Y +11 F $d^1 s^2$ | Zr 0 $d^2 s^2$ | Nb −9 F $d^4 s^1$ | Mo −13 F $d^5 s^1$ | Tc | Ru −16 B $d^7 s^1$ | Rh −16 B $d^8 s^1$ | Pd −14 B $d^{10}$ | Ag −10 F $d^{10} s^1$ | Cd −3 F $s^2$ | In +4 F $s^2 p^1$ | Sn −3 F $s^2 p^2$ | Sb −1 F $s^2 p^3$ | Te +1 F $s^2 p^4$ |
| 6 | Cs +67 U $s^1$ | Ba +39 U $s^2$ | La +17 U $d^1 s^2$ | Hf −1 F $d^2 s^2$ | Ta −9 F $d^3 s^2$ | W −13 F $d^4 s^2$ | Re −14 B $d^5 s^2$ | Os −15 B $d^6 s^2$ | Ir −15 B $d^7 s^2$ | Pt −13 F $d^9 s^1$ | Au −10 F $d^{10} s^1$ | Hg −2 F $s^2$ | Tl +7 F $s^2 p^1$ | Pb +8 F $s^2 p^2$ | Bi +6 F $s^2 p^3$ | Po +10 F $s^2 p^4$ |
| 7 | Fa $s^1$ | Ra $s^2$ | Ac $d^1 s^2$ | Th +11 F $d^2 s^2$ | Pa | U −5 F | | | | | | | | | | |

Atomic Symbol → Sn
Size Factor, % → −3 F
Configuration of Outer Electrons → $s^2 p^2$

F = Favorable
B = Borderline
U = Unfavorable

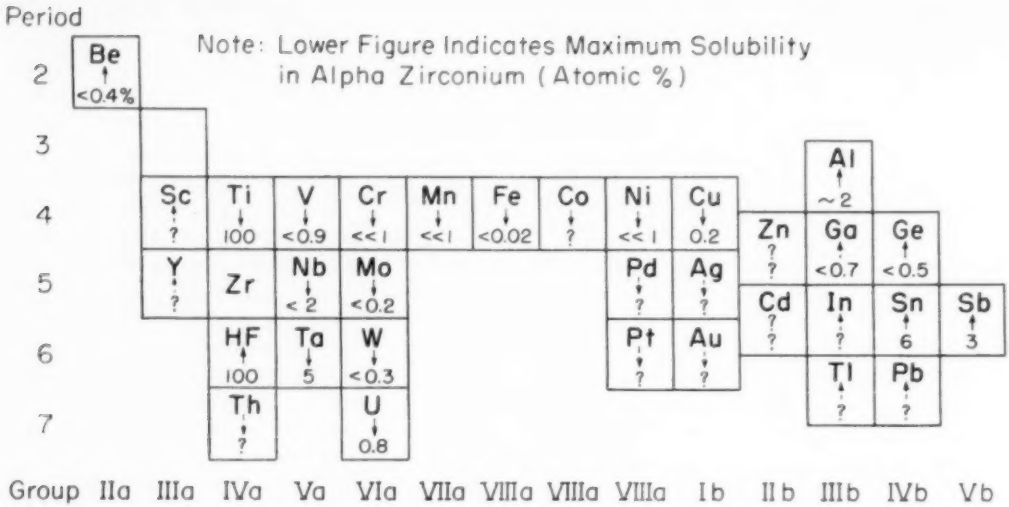

Period
Note: Lower Figure Indicates Maximum Solubility in Alpha Zirconium (Atomic %)
2
3
4
5
6
7
Be <0.4%
Sc ? Ti 100 V <0.9 Cr <<1 Mn <<1 Fe <0.02 Co ? Ni <<1 Cu 0.2
Y ? Zr Nb <2 Mo <0.2 Pd ? Ag ?
HF 100 Ta 5 W <0.3 Pt ? Au ?
Th ? U 0.8
Al ~2
Zn ? Ga <0.7 Ge <0.5
Cd ? In ? Sn 6 Sb 3
Tl ? Pb ?
Group IIa IIIa IVa Va VIa VIIa VIIIa VIIIa VIIIa Ib IIb IIIb IVb Vb

*Fig. 2 – Solubility of Potential Alloying Elements in Alpha Zirconium and Their Effect on the Transformation Temperature. The arrow indicates the direction of transformation shift; dashed arrow is predicted, solid arrow has been determined*

beta and alpha phases. Inasmuch as zirconium's transformation temperature lowers with the addition of titanium and rises with the addition of hafnium, these must be manifestations of second-order effects, and may represent the preferential ordering of one phase (the beta phase, in the case of titanium).

From these considerations, it is seen that zirconium generally follows the same rules of alloying as do iron and titanium. Differences in size, electrochemical effect, and crystal structure change the identity of the elements with respect to their tendency to form solid solutions. However, the effects of a potential solid-solution former are the same in zirconium as in titanium and iron. Elements such as Cb, Ta, Mo, W, V, U, Cr, Mn, Fe, Co, Ni, and Cu, with a larger number of outer *d* electrons, can be expected to be eutectoid formers, to enlarge the beta field, and to lower the transformation temperature. Elements such as B, Al, Sn, Ge, Sb, Pb, Tl, and In, with a smaller number of outer *d* electrons, can be expected to have the reverse effect. The effects of Zn and Cd, which are borderline, are difficult to predict. If crystal structure plays a part, it might be expected that the α phase would be stabilized. The elements O, N, and C apparently act in zirconium alloys as they do in titanium – they are alpha stabilizers and raise the α to β transformation temperature. Solubility of silicon is very low; however, the indications are that it is a peritectoid former.

While this criterion is interesting from a theoretical viewpoint, its practical implications are many. Hot fabrication ranges, recrystallization temperatures, and high-temperature creep strengths can be inferred, and the determination of equilibrium diagrams can be considerably simplified.

## EFFECT OF TEMPERATURE ON TENSILE PROPERTIES

**Unalloyed Zirconium** – A comparison of the tensile properties of zirconium with iron and titanium is very difficult because of the large effect of small impurities. Bureau of Mines' sponge zirconium produced prior to 1950 had tensile strengths ranging from 75,000 to 85,000 psi. Sponge zirconium produced in 1950 and melted in graphite crucibles had an annealed tensile strength of 58,000 psi. and as low as 48,000 psi. for sponge similarly produced in 1952. This progressive reduction parallels the purification of the sponge. Arc-melted iodide zirconium, rolled and annealed, may now be expected to have a yield strength of 10,000 to 15,000 psi. and a tensile strength of 28,000 to 40,000 psi. Both the sponge and iodide zirconium are ductile, having over 30% total elongation in the annealed condition.

Elevated temperatures are slightly more effective in decreasing the tensile strength of zirconium (both iodide and sponge) as compared with temperature effects upon low-carbon steel and titanium, shown in Fig. 3. Composition differences probably are respon-

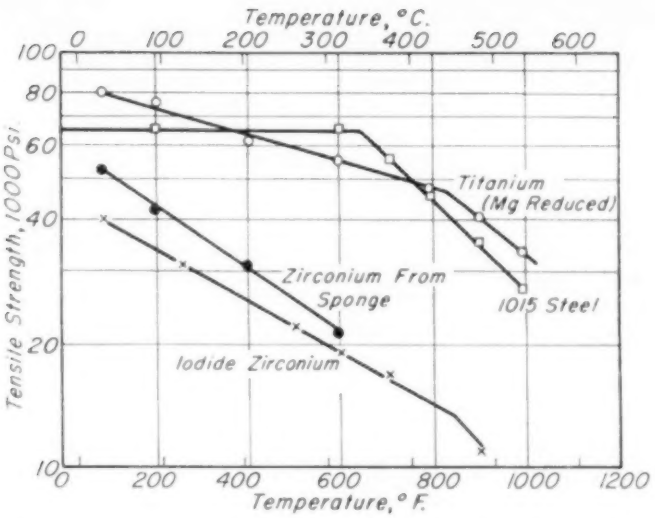



*Fig. 3 – Effect of Temperature on Short-Time Tensile Strength*

sible for the spread between zirconium and titanium, and it is probable that minor impurities raise the strength of titanium more than zirconium. For example, the tensile strength of annealed iodide titanium sheet, which averages about 32,000 psi., is similar to that of annealed iodide zirconium sheet, which ranges from 28,000 to 40,000 psi. When impurities are added to these two rather pure base metals, the strength levels are raised. Magnesium-reduced titanium has approximately the same impurity level as sponge zirconium, but it is apparently much stronger.

The effects of temperature on the hardness of zirconium, titanium, and 1020 steel are shown in Fig. 4. Differences in melting practice produce marked changes in the hardness (and similarly strength) of zirconium. Melting iodide zirconium in a graphite crucible, which introduces carbon, increases the Brinell hardness at room temperature by 50% over that of arc-melted iodide zirconium. This effect decreases rapidly with increasing temperature as the hardening influence of the carbide phase is reduced. The curve for the mild steel is included to show the same effect as noted in Fig. 3.

There is an approximate proportionality between the hardness and tensile strength of zirconium, valid both at room and elevated temperatures. The diamond pyramid hardness number in kg. per sq.mm. multiplied by 330 is a good indication of the tensile strength in psi. This multiplier is not equal to the proportionality constants

## Tensile Properties of Zr

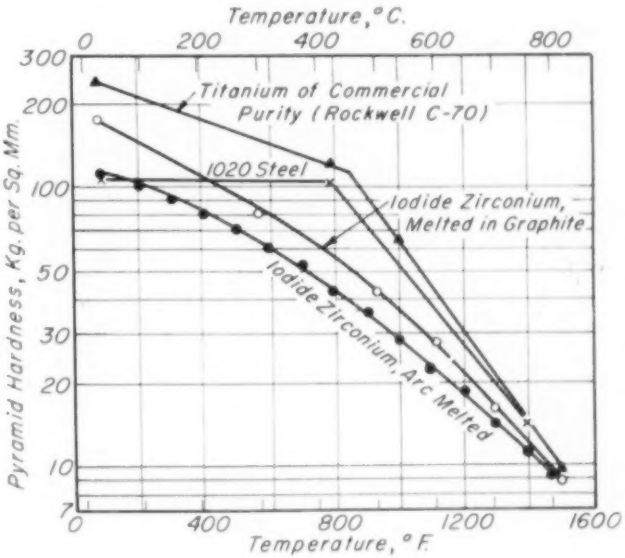
for titanium and steels, and this is a prime reason why alloys of various base metals should not be compared on the basis of hardness numbers.

**Zirconium Alloys** – Research on the development of zirconium alloys for high-temperature strength has been only recently undertaken and much remains to be done. However, it appears that zirconium alloys are rapidly approaching commercial titanium alloys with respect to tensile strength at 900° F. and are equal, if not superior, in creep strength* at that temperature.

A comparison of the effects of binary additions on induction-melted iodide zirconium alloys is shown in Table I. Zirconium with 1.3% molybdenum alloy has very good tensile properties at room temperature – a yield strength over 100,000 psi., a tensile strength over 120,000 psi., with 8% elongation. All the zirconium alloys listed here were tested as sheet after annealing at 1300° F. It is apparent that relatively small additions of a second metal to zirconium have produced major changes. The stress to cause rupture

*Creep strength is here defined as the stress to cause a secondary creep rate of 0.0001% per hr.

*Fig. 4 – Effect of Temperature on Diamond Pyramid Hardness of Annealed Sheet*



## High and Low-Temperature Properties

in 100 hr. at 930° F. (500° C.) for the 4.8% Sn alloy, one of the few tested, was 26,000 psi. This is comparable to the 100-hr. rupture stress of 20,000 psi. for Ti-150A.

The development of zirconium alloys for elevated-temperature service can be expected to proceed in the same manner as other high-temperature alloys. When temperatures below 750° F. are involved, considerable strengthening can be obtained by solid-solution alloying and by formation of a second phase. The transient creep stage is important in this temperature range because the stresses are high and the transient deformation constitutes the greater portion of the total deformation. As the temperature is raised above 750° F. into the region of greater atomic mobility, elements which are solid-solution formers are likely to be of more importance than elements which form second phases. However, since grain-boundary movements constitute a large portion of the deformation process, stable compounds present in the grain boundaries serve to reduce the deformation by a keying or locking action. Elements which are most effective in raising recrystallization temperature should be most effective in reducing creep at 750 to 1100° F.

For creep strength in this higher range, the alloying elements should not have interatomic radii too different from zirconium. It is estimated that the size factor should vary from 6 to 10% for optimum strengthening at 925° F. (500° C.). The *d* electron consideration becomes important, and it is to be expected that elements which raise the transformation temperature should promote high-temperature strength. Examples are aluminum, tin and titanium. Titanium, although not a peritectoid former, has complete solid solubility, and the zirconium lattice can be strengthened to a greater degree than with elements which produce greater distortion and therefore phase separation.

### LOW-TEMPERATURE EMBRITTLEMENT

The early history of zirconium showed that it had relatively low energy-absorbing capacity in the notched-bar impact test. It was regarded as a typical hexagonal metal with inherently low impact strength at room temperature – that is, less than 20 ft-lb. The impact energy increases with temperature, reaching values of 80 ft-lb. or more above 400° F. The shape of the curve of impact energy versus temperature resembles the transition curve of steels (Fig. 5). Recently, it has been found that upon annealing at 1475° F. (800° C.) in a vacuum of less than 0.1 micron, the room-temperature impact energy could be as high as 70 ft-lb. Analysis showed that hydrogen was removed from the metal, and the term "hydrogen embrittlement" takes on a new meaning when applied to zirconium. A comparison with a typical curve of S.A.E. 3130 steel by J. H. Hollomon and co-workers (*Transactions* ASM, 1947, p. 807) is shown in the two lines at left in Fig. 5. (The zirconium specimens were standard V-notch Charpy bars.) The similarity between the S-shape of these two curves is striking, although it should not be assumed that the underlying reasons for such behavior are the same. The effect of hydrogen in titanium is reported to be similar, and the embrittling effect can also be removed by high-temperature vacuum treatment.

The effects of various amounts of hydrogen on the impact strengths of a 98.5 Zr, 1.5 Sn alloy are also shown in Fig. 5. The transition from tough to brittle behavior is also verified by measurements of the reduction in width directly below the notch. In steels, this transition is normally associated with the interstitial elements such as carbon and nitrogen, or with hydrogen embrittlement resulting from pickling or electroplating, and these atoms are

*Fig. 5 – Charpy Impact Strength at Various Temperatures of Zirconium Plus 1.5% Tin and Increasing Amounts of Hydrogen*

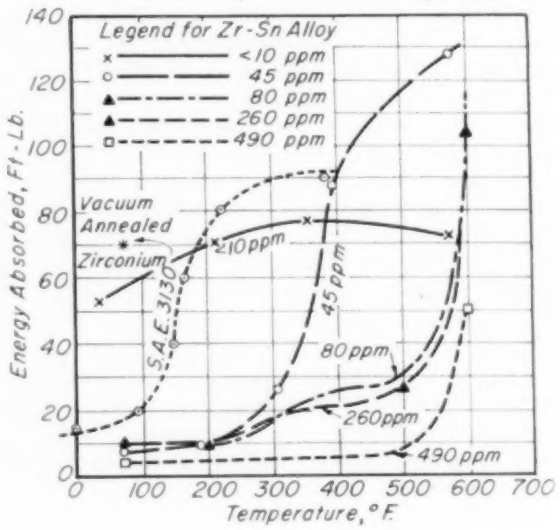


**Table I – Yield and Tensile Strength at 930° F. (500° C.)**

| Metal | Yield | Ultimate |
|---|---|---|
| Zirconium (unalloyed) | 8,800 psi. | 14,300 psi. |
| Zirconium alloys | | |
| 2.0% aluminum | 32,000 | 46,000 |
| 1.3% molybdenum | 49,000 | 74,000 |
| 2.2% columbium | 35,000 | 43,000 |
| 6.4% tantalum | 27,000 | 34,500 |
| 10.4% titanium | 41,000 | 58,000 |
| 4.8% tin | 24,000 | 32,000 |
| Titanium | | |
| RC-70 (commercial titanium) | 29,000 | 40,000 |
| Alloy RC-130A | 38,000 | 72,000 |
| Alloy Ti-150A | 40,000 | 55,000 |
| MST, 3 Al - 50 Cr | 70,000 | 100,000 |
| Steel | | |
| 1015 | 20,000 | 33,000 |
| Type 316 stainless | 25,000 | 72,000 |

in solution and not present necessarily as precipitates. In zirconium, the low impact strength has been primarily associated with the appearance of hydride needles. When the needles are absent, as after quenching from above 600° F., the material usually is found to be tough. Exceptions occur when the hydrogen content is relatively high – say, more than 100 parts per million.

Although the causes of the embrittlement in zirconium and iron apparently are not the same, the relative effects of a notch and strain rate upon the two metals are similar. It is accepted that it is the notch which raises the effective yield stress in iron to the fracture-stress level and causes the brittle behavior. Strain rate has only a relatively minor effect in shifting the transition curve along the temperature axis. In zirconium, although it is thought to be somewhat more sensitive to strain rate than iron, essentially the same effects are noticed. Tensile-impact tests on unnotched sheet of normally embrittled material show the material to be tough at −300° F. (−180° C.). Specimens notched with a jeweler's saw had reduced toughness at this temperature, but did not show a completely brittle behavior. On the other hand, impact-bend tests on the same material, using V-notch Charpy specimens, showed completely brittle behavior when tested at room temperature.

Apparently, the same variability of results as influenced by test specimens and procedure will be present in work on zirconium-base alloys as is found in iron-base alloys.

**Summary** – Zirconium, although of only relatively recent major interest, has been the subject of intensive research which has indicated that it may be compared profitably with other metals, such as iron and titanium. It appears that effects common to iron and titanium are also common to zirconium. The effects of alloying elements on equilibrium diagrams and the high-temperature strength can be predicted with a fair degree of accuracy; thus research can be directed along productive directions. Low-temperature brittleness, which is a major problem in steels, should also be expected in zirconium, but efforts to eliminate or control this brittleness in zirconium and its alloys have made rapid progress.

*Fig. 6 – Zirconium Crystal Bars Produced by the Iodide Process From Crude Zirconium Sponge Furnished by the Bureau of Mines. Courtesy Atomic Power Division, Westinghouse Electric Corp.*

# Rapid Calculation of Microhardness Numbers

THE CALCULATION of indentation microhardness numbers by the usual method is often laborious, particularly when many measurements are to be made. The microscope ocular reading must be multiplied by the microscope calibration factor, a table consulted and the value found from the table finally multiplied by the indenting load. Nomograms have been developed for the purpose (see "Alignment Chart for Computing Diamond Pyramid Hardness Number", by H. Robinson, *Metal Progress*, August 1945, p. 288, and data sheet, "Nomogram for Diamond Pyramid Hardness", p. 296-B of the same issue), but are scarcely satisfactory for continuous use. The calculations can, however, be greatly simplified by two slide-rule methods which combine the multiplication constants, or even further by the use of a special-purpose slide-rule calculator.

For both the 136° pyramid (Vickers) and the Knoop indenter, the hardness number H is calculated from the impression diagonal D and the indenting load L by the formula:

$$H = \frac{KL}{D^2} = \frac{KL}{d^2M^2}$$

where K is the indenter constant (1.854 for the Vickers indenter and 14.23 for the Knoop indenter), d the microscope ocular reading, and M the microscope calibration factor.

**First Method** – Factor $L/M^2$ is constant for a particular test; therefore a table of constants can be readily drawn up for all normal combinations of load and microscope objective. The second factor, $K/D^2$, can be found from standard hardness tables, since it will be that value which corresponds with the ocular reading (instead of impression diagonal) for an indenting load of 1 kg. The calculations are then carried out as follows:

1. The appropriate load-microscope calibration constant is found from the previously prepared table.

2. From the standard table for the indenter of 1-kg. load, the value corresponding with the impression ocular reading is obtained. This value is multiplied by the constant found in step 1 on a standard slide rule.

It will be noted that the latter multiplication can be handled for any number of indentations of a series with one setting on the slide rule.

**Second Method** – The entire set of constants $KL/M^2$ can be combined and a table of constants drawn up for each indenter. The constant has then only to be multiplied by $1/d^2$ (reciprocal of $d^2$), and this can be done on a slide rule as follows:

1. The appropriate constant is selected from the table for the indenter in use.

2. With the slide of a standard slide rule turned end for end so that the "A" and "C" scales are in juxtaposition, the index of the "C" scale is set against the value of the "A" scale corresponding with the constant found in step 1.

3. Thereafter, if the cursor is set to the ocular reading value on the "C" scale, the corresponding hardness number is found under the cursor on the "A" scale.

**Microhardness Calculator** – The calculations can be combined in the special-purpose slide rule illustrated in Fig. 1. In the basic (lower) scale of the calculator, the linear logarithm scale (called "ocular reading") runs in a clockwise direction and this is aligned against a counterclockwise square scale (called "hardness number") so that the indices are displaced to incorporate multiplication by K. This scale enables calculation of $K/D^2$. A separate base scale is therefore required for each indenter. The multiplication of M by d can be carried out with the central clockwise linear scale; this scale is labeled "microscope calibration" and marked with a range of values required to accom-

By L. E. SAMUELS and T. O. MULHEARN, Defense Research Laboratories, New South Wales Div., Sydney, Australia

modate the standard objectives supplied with the Wilson Tukon machine. The calibration factors for the optics of a particular measuring microscope can be permanently marked on the scale. On the upper "indenting load" disk, convenient indenting load values are arranged on a counterclockwise square scale, for final multiplication by L.

The three disks and a radial cursor are mounted on a spindle in such a way that the disks for "microscope calibration" and the "indenting load" and the cursor can be locked together and thereafter be rotated as a unit with respect to the "hardness scale" disk. The type of spindle required is shown in Fig. 2. The calculator is then used as follows:

1. The index of the "indenting load" disk is set to the calibration factor of the microscope objective in use.
2. The cursor is set over the indenting load.
3. The cursor and top two disks are locked together by tightening the top knurled knob.

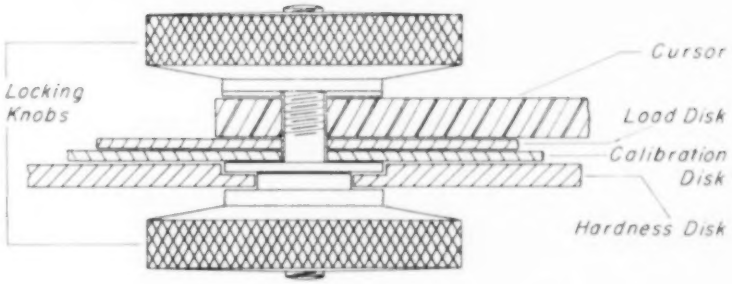
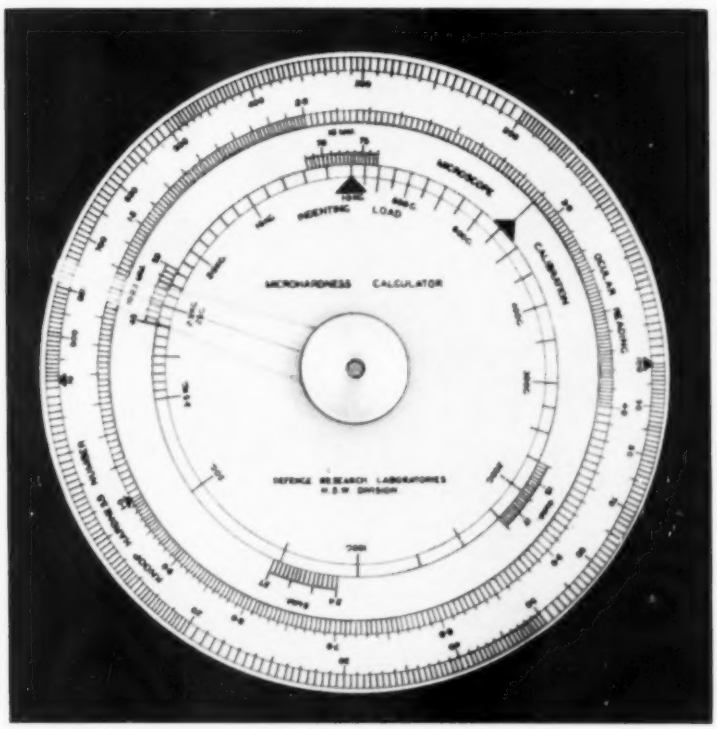



*Fig. 2 – Sketch of Spindle and Disk Assembly*

4. Thereafter, when the index of the "microscope calibration" disk is set to the ocular reading, the corresponding hardness is found under the cursor on the "hardness scale".

*Fig. 1 – Microhardness Calculator With Setting for 16-Mm. Objective and 2.5-Kg. Indenting Load; an Ocular Reading of 2.90 Gives a Hardness Number of 770 as Read by the Cursor on the Outer Disk*




## DISCUSSION

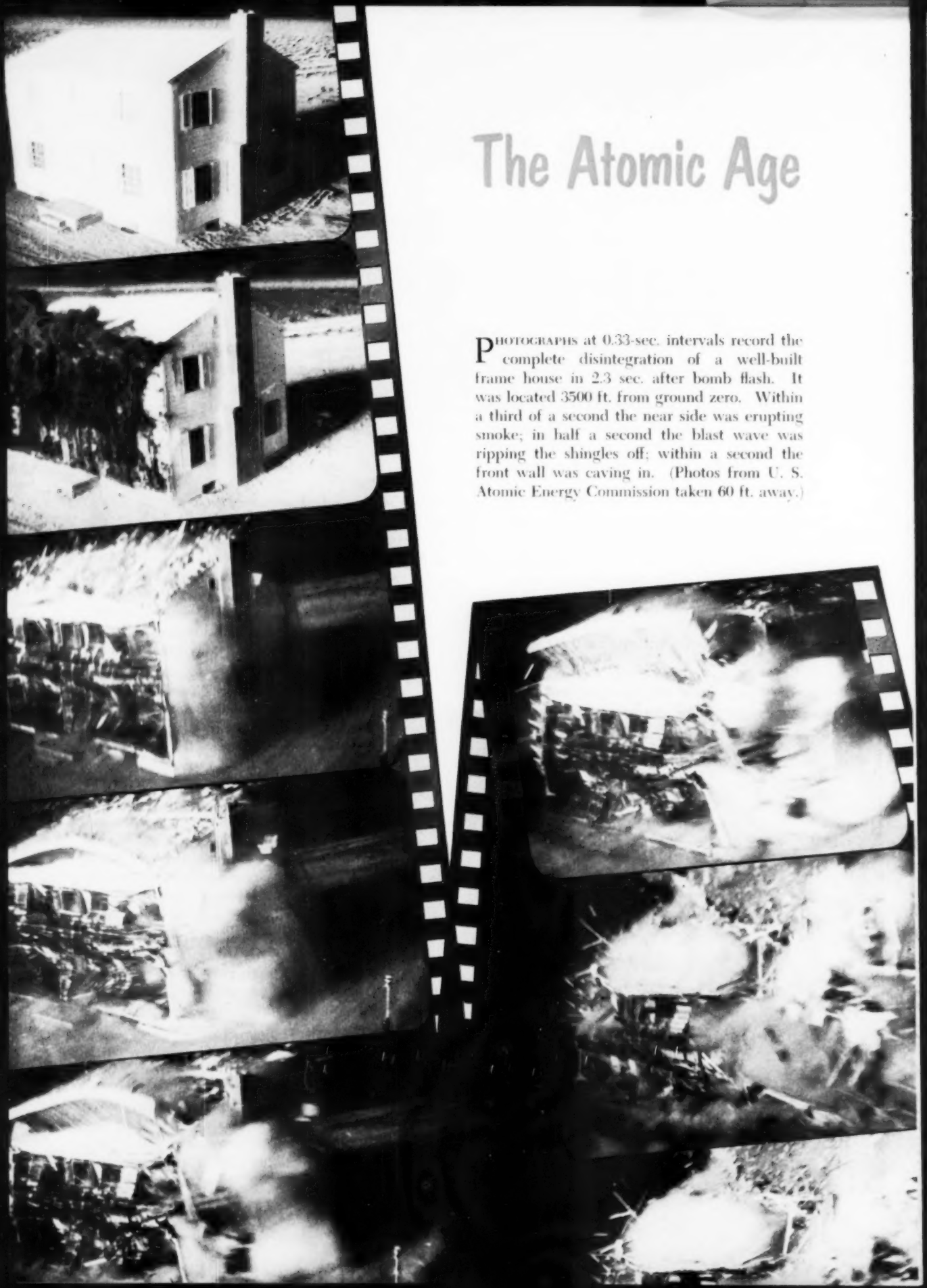
Of the methods that are described above, each of the slide-rule methods involves only a single setting of the slide for a given combination of indenting load and measuring optics; they are consequently rapid and not subject to cumulative errors arising from setting of the scales. Once the operator becomes familiar with the reversed slide procedure, he will find the second method to be more rapid and convenient than the first method.

The calculator, as characteristic of a special-purpose instrument, is the simplest of the three methods to use. However, it is probably worth constructing only if large numbers of calculations have to be made. It is to be noted that the slide-rule methods are applicable only where a constant microscope-calibration factor can be assumed. If the microscope is precisely calibrated and the calibration factor found to vary with size of impression, as suggested by E. B. Bergsman, *A.S.T.M. Bulletin* No. 176, September 1951, p. 137, only the calculator can be used accurately.

In common with all slide-rule calculations, some care is necessary in all three methods to insure that the hardness number obtained is of the right order; the correct order is, however, usually known to the user.

**Acknowledgment** – The authors are indebted to E. G. Thurlby for suggesting the second slide-rule method and to the Chief Scientist, Department of Supply and Development, for permission to publish this paper.

# The Atomic Age



PHOTOGRAPHS at 0.33-sec. intervals record the complete disintegration of a well-built frame house in 2.3 sec. after bomb flash. It was located 3500 ft. from ground zero. Within a third of a second the near side was erupting smoke; in half a second the blast wave was ripping the shingles off; within a second the front wall was caving in. (Photos from U. S. Atomic Energy Commission taken 60 ft. away.)

# Processing of Boron Steels in the Shop*

By G. D. RAHRER
Metallurgist, Alloy Division, United States Steel Corp., Pittsburgh

WE NEED NOT review the reasons for the necessity of conserving our supply of alloying elements, particularly nickel and molybdenum, by using boron-treated, low-alloy steels. In the 1940's there were a few, but only a few, steel fabricators who used large tonnages of the boron-treated steels. However, since 1950 their consumption increased to about 10% of all alloy steels.

Assuming (as I think is proper) that desired mechanical properties in heat treated parts attained by straight alloy steels can also be obtained with boron-treated steels, let us turn our attention to another consideration. In most manufacturing operations, *cost* as well as satisfactory properties of the finished product is important. So the performance of a steel in processing *prior* to heat treating is of interest to new users of boron steels. To be discussed in this article are processing steps as follows: machining; punching; cold forming, such as cold heading and hobbing; hot forming (forging and rolling); and welding.

## MACHINING

In the processing of manufactured steel parts, machining usually constitutes the most costly group of operations. Let us consider, then, the factors which influence the machinability of steels. The most important of them are *(a)* hardness, *(b)* structure, *(c)* inclusions, and *(d)* composition.

**Microstructure** – For steels with wide differences in hardness, the steel which has a greater hardness will generally have the lower machinability. However, most everyone knows that two steels of about the same hardness may machine quite differently.

One factor controlling hardness which we can change by treatment is structure, and it is by far the most important of the controllable factors. For example, consider the following data for ⅞-in. rounds of modified 9260 + Mo (0.57 C, 0.67 Mn, 0.014 P, 0.020 S, 1.74 Si, 0.44 Mo). Annealing at 1600° F. gave a structure of 50% lamellar pearlite and Brinell 217 – the same hardness as when spheroidized (small carbides in ferrite). This was cut dry with plain carbon toolsteel, 0.050-in. cut, 0.002-in. feed. Cutting speed for tool life of 60 min. was 110 ft. per min. for the annealed structure, 77 for the spheroidized. (Dimensions of the tool were: ⅜ x ⅜ in.; 15° back rake, 6° side rake, 6° front clearance, 6° side clearance, 0.031-in. nose radius.)

The same steel with the same hardness machined quite differently because of difference in structures. In general, comparatively soft, yet brittle, structures are easy to machine.

*Lecture in the Indianapolis Chapter ASM Educational Course, 1952.

## Annealing for Machinability

Thus, a coarse pearlite or a combination of a lamellar and spheroidized structure would be generally preferable to a tempered martensitic structure for turning operations on 1040 and 4340, as far as machinability is concerned.

Another element of microstructure is inclusions, particularly the sulphides. Their influence on machinability is well known.

Composition has some effect but not as much as might be supposed if other factors, especially structure, are the same. If we are comparing machinability of two steels in the hot rolled or normalized condition, then, of course, composition could have a great effect. For instance, a hot rolled 3-in. round of 4340 with about 3% of alloy would be much harder to machine than plain carbon 1040. However, by proper treatment, we can make the tough 4340 nearly as easy to machine as 1040.

Now the machinability of boron steels is influenced by these same factors. The ease or difficulty of getting the steel into a machinable condition by controlling the structure depends on its isothermal transformation behavior. To see why this is so, let us consider the differences between TS86B45H and 4340H, as shown in Fig. 1. Both have about the same hardenability as shown by end-quench tests, at least as far as 12 to 14 sixteenths on the Jominy bar, when the slight difference in carbon content is allowed for. S-curves are compared in Fig. 2, and there is not a great deal of difference in the shortest time of nucleation, the "nose" of the S-curve, being about 10 sec.

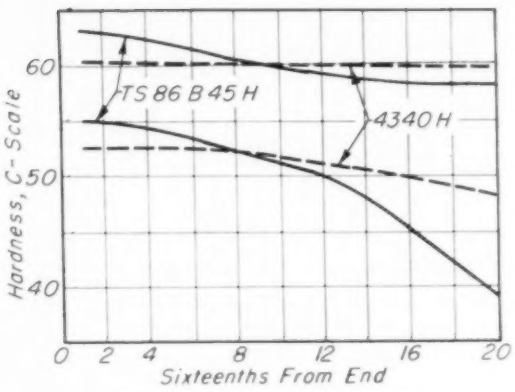



*Fig. 1 – Comparative Hardenability Bands of TS86B45H and 4340H*

for 4340 and about 20 sec. for 86B45. However, the shortest time to *finish* transformation for the 86B45 is about 700 sec. or 11½ min. (at 1200° F.) and for the 4340, about 10,000 sec. or 2.8 hr. (also at 1200° F.). So it is evident that if we were annealing, either by a "full" anneal or an isothermal annealing cycle, the time required for the boron-treated would be much less than for the old 4340 Ni-Cr-Mo steel. A corollary is that, in the same sizes, hot rolled from the same mill, 86B45 will have more ferrite and coarse pearlite, and be softer.

To illustrate further, suppose we consider transformations of two steels, both of the same composition except that one steel contains boron. Figure 3 shows that at fast cooling rates the boron-treated 1060 will transform to martensite and will be hard, whereas it would be difficult to quench regular 1060 fast enough

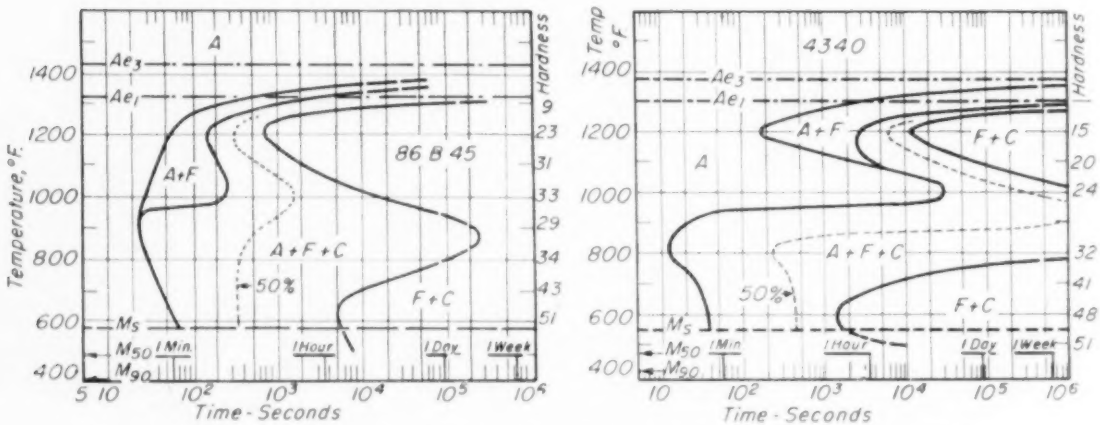



*Fig. 2 – S-Curves for 86B45 and 4340, According to Research Laboratory, U. S. Steel Corp., Show End of Isothermal Transformation at Advanced Times. Hardness of 86B45, isothermally annealed at or above 1000° F., is somewhat higher than 4340, correspondingly treated; part of this is due to the slightly higher carbon content*

to avoid the production of a little ferrite. At slower cooling rates, as in annealing, both will transform to ferrite and pearlite, and be equally hard. This means that for heat treatments involving slow cooling, we can schedule the same routines for a boron and a non-boron grade.

Now to consider how boron-treated steels compare in machinability with straight alloy steels of equivalent hardenability so as to be regarded as alternate steels for the same parts. First, I will present some laboratory machinability tests of the "tool-life" type wherein the tool's shape, the depth of cut and pitch are standardized. Usually no coolant plays on the tool. Cuts are made at various speeds until the tool fails, and a graph plots surface speed against time to failure, from which is read surface speed for failure at say 60 min. Shorthand notation for this is V60.

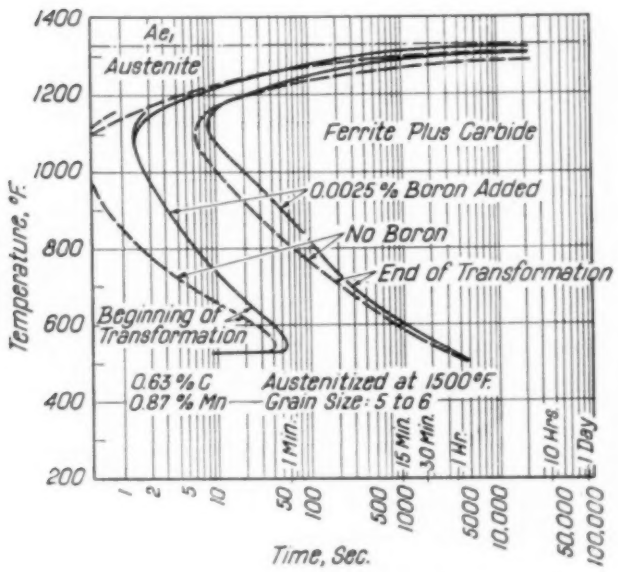



*Fig. 3 – Boron Added to 1060 Steel (0.63 C, 0.87 Mn) Moves the S-Curves Bodily to Right. (U. S. Steel Corp.)*

Table I, page 88, gives data of this sort on the machinability of 2½-in. rounds of 4140 and 4340 (lamellar pearlite and 50% spheroidized) made at Gary Steel Works Research Laboratory. 4140 and 41B40 (0.40 C, 0.87 Mn, 0.032 S, 0.31 Si, 0.04 Ni, 0.94 Cr, 0.22 Mo) were tested in two structural conditions, *(a)* 50% spheroidized and *(b)* coarse lamellar pearlite. The tool was of the same dimensions as quoted early in this article; it was, however, of high speed steel. Comparing V60 for 4140 and 41B40 in both microstructures at approximately equivalent hardness (Brinell 170 ± 8), the results in Table I indicate that boron decreases machinability slightly. Two heats of 4340 – quite similar to the 4140 except for 1.74 Ni – were also tested in 50% spheroidized condition. One heat with 0.020 S, Brinell 197 hard, had V60 of 200 ft. per min. The second heat with 0.040 S, Brinell 207 hard, had V60 of 248 ft. per min. This indicates that a boron steel can be machined faster than a higher alloy steel of the same hardness and structure. (Note the effects of 0.020 and 0.040% S in the 4340 samples, since reference will be made to this later.)

Another tool life test summarized in Table II compares 13B45 (0.44 C, 1.58 Mn, 0.020 S, 0.31 Si, 0.01 Ni, 0.04 Cr, 0.01 Mo, 0.001 B) with 4145 (0.45 C, 0.95 Mn, 0.024 S, 0.24 Si, 0.06 Ni, 0.91 Cr, 0.20 Mo), in three microstructures and in fine and coarse feed. These results show that with light cuts 13B45 machines much more easily in the pearlitic condition but 4145 has the advantage in the fully spheroidized condition. The 4145 machines slightly more easily with the heavy cut. It should be noted that the low sulphur of the 13B45 steel impairs machinability, as was observed in Table I comparing 41B40 and 4140. Its rating would be considerably improved by a one-fifth greater sulphur content, making it equal to that of the 4145.

**Manufacturing Data** – One of the parts for which we have manufacturing data on pieces machined per tool grind is for shock absorber link studs, made alternatively of 13B45 (0.40 C, 1.58 Mn, 0.018 S, 0.30 Si, 0.02 Ni, 0.05 Cr, 0.01 Mo) and 9445 (0.47 C, 0.99 Mn, 0.025 S, 0.21 Si, 0.51 Ni, 0.40 Cr, 0.12 Mo). These were heat treated to 212 to 229 and 207 to 223 Brinell respectively. The figures below show that on most operations the 13B45 caused faster tool wear; contributing factors were its much lower sulphur content and its higher hardness.

| | Pieces per Tool Grind | | Relative |
|---|---|---|---|
| Operation | 13B45 | 9445 | Machinability |
| Rough form taper | 684 | 912 | 75% |
| Rough turn stud | 328 | 533 | 62 |
| Rough form ball | 596 | 760 | 78 |
| Finish turn stud | 347 | 521 | 67 |
| Finish ball and taper | 912 | 1064 | 86 |
| Shave ball and taper | 476 | 483 | 99 |
| Thread end, ¾ in. - 16 | 982 | 912 | 108 |

## Cold Forming Operations

Another manufacturer of heavy earth-moving equipment has used 25,000 tons of TS86B45 during the last nine years for parts formerly made of 4340. These are axle shafts, wheel spindles and steering knuckle arms. It has been found that TS86B45 can be annealed in a shorter time and the machining time per part is 25 to 30% less than for 4340. Heat treatment prior to machining is as follows for TS86B45: Heat 2 hr. at 1600° F., cool to 800, reheat to 1380, cool to 1210° F. and hold 3 hr., cool in air. Old heat treatment for 4340 was to heat to 1450° F. and hold 1 hr. per inch of section, cool no faster than 20° per hr. to 1175° F., then cool in air.

**Carburizing Steels** – Let us now turn to the carburizing steels, on which various manufacturers have considerable experience. A maker of heavy earth-moving machinery had long used the 8622 for large ring gears and pinions, and a couple of years ago changed to TS-94B17. 8622 had been annealed in an 8-hr. cycle; TS94B17 could be prepared for machining with a 1-hr. normalize and a 1-hr. tempering or stress-relieving treatment. Experience has shown that the boron steel machined somewhat better on turning operations but was slightly inferior in broaching. While the machinability of the two steels is not greatly different, the preparation for machining is; note the reduction from an 8-hr. cycle to 2 hr.

No appreciable difference in machine shop costs was noted when substituting 80B20 for 8620 in automotive transmission gears. 8620 required an 8-hr. cycle anneal to give 149 to 156, while the 80B20 is a little softer (137 to 149) after 1 hr. at 1700° F. and 4 hr. at 1150.

**Table II – Variation of V10* of 13B45 Versus 4145 in Various Microstructures**

| Structure | Brinell | V10* for 13B45 | V10* for 4145 |
|---|---|---|---|
| Light Cuts: 0.002-In. Feed, 0.050-In. Cut | | | |
| Coarse pearlite | 229 to 241 | 360 | 273 |
| 50% spheroidal | 212 to 223 | 282 to 295 | 273 |
| 100% spheroidized | 201 to 212 | 435 | 500 |
| Heavy Cuts: 0.0127-In. Feed, 0.050-In. Cut | | | |
| Coarse pearlite | 229 to 241 | 131 | 142 |
| 50% spheroidal | 212 to 223 | 173 | 180 |
| 100% spheroidized | 201 to 212 | 206 to 227 | 191 |

*Ft. per min. for 10-min. tool life.

A rock bit manufacturer has noted little difference in machinability between 46B12 and 4812. At this plant various annealing and normalizing treatments are being tried to improve the machinability of the boron steel.

It is appropriate to re-emphasize that minimum hardness does not mean best machinability. Disregard of this fact may be one source of difficulty with boron steels for carburized parts. Many of the older low-alloy carburizing steels are normalized for machining. A boron steel of the same hardenability will, on normalizing, contain more ferrite and hence be softer, sometimes to the point of being gummy under machine cutting.

### COLD FORMING, COLD HEADING, HOBBING

Cold forming operations include cold heading, punching, and cold drawing. The main objective in these operations is to achieve low hardness; a low alloy content is a minor factor.

**Table I – Machinability of 4140 Versus 41B40**

| Microstructure | 4140 | | 41B40 | |
|---|---|---|---|---|
| | Hardness | V60* | Hardness | V60* |
| 50% spheroidized | 163 | 338 | 170 | 293 |
| Coarse lamellar pearlite | 170 | 327 | 179 | 287 |

*Ft. per min. for 60-min. tool life.

35,000 tons of TS14B35 has been used in cold headed bolts in the past 10 years by the Caterpillar Tractor Co. Die life when working on the boron-treated steel versus the steel formerly used, 8640, is shown below.

| | Pieces per Grind | |
|---|---|---|
| | 14B35 | 8640 |
| Trimmer dies | 22,100 | 9,000 |
| Shear dies | 400,000 | 150,000 |
| Rolled thread dies | 200,000 | 150,000 |

Point cutters will run 4 hr. per grind on the boron-treated steel, four times the life on 8640. The effect of lower carbon and lower alloy steel on wear of dies and thread cutter is very evident. Other producers of heat treated bolts have also increased their use of boron steels. The tonnage of 14B35, TS40B32 and TS40B37 for alloy bolts has increased until these grades constitute a considerable part of the production of bolt wire.

Another cold forming operation is drawing. As early as 1943, annealed 13B45 was cold drawn for machining into parts of the M-1 rifle in the experimental production of parts formerly made of 4145.

50B60 and 51B60 are being used for leaf springs, replacing 4068, 5160 and 8660. Usually the rolled flats are stacked on the mill hot bed for slow cooling to a soft structure, but occasionally spring fabricators break a punch, or a shear is damaged by a hard spot. Mill experience has shown that, because of the faster transformation of boron steels with leaner alloy content, the resulting structure has a lower hardness and tool casualties are therefore correspondingly less.

### HOT FORMING AND WELDING

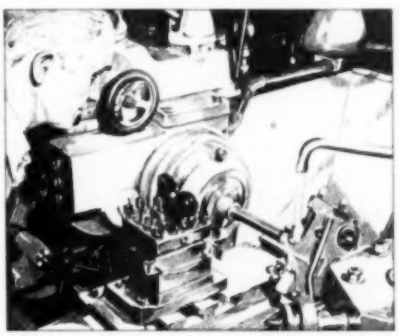
Hot forming of boron steels consists of rolling and forging. The main factor affecting hot workability is the alloy content; in general, the higher the alloy content the stiffer and the harder is the steel to work. (Stainless steels and steels designed for creep resistance are difficult to roll and forge for this reason.)

Boron added to a steel to increase hardenability after quenching seems to have very little effect on the hardness of the hot steel (austenite) before quenching. Consequently, a boron steel chosen to replace one with a higher alloy content usually forges more easily. Furthermore, the scale formed is flakier and more easily cleaned than on certain of the older, conventional steels.

An outstanding example of such experience has been reported by Robbins and Lawless on p. 42 of the booklet on "Boron Steel". They estimate a minimum saving of 25% in die costs in the 10,000 tons of 14B45 processed.

A summary of results in another plant when forging TS14B45 and 9445 shows that 22,000 to 25,000 pieces of TS14B45 could be forged per die-sink and the dies were then in noticeably better condition than they would be after making 13,000 to 15,000 pieces of 9445. The boron-treated steel forgings could be cleaned up in 15 min. in the shot-blast; the 9445 forgings required 20 min.

A producer of rotary rock bit cutters formerly used 4812 exclusively. Five years ago, this plant started using 46B12. Forging was found to be easier and the cleaning of forgings for machining less expensive. In other large tonnage uses (one of 94B17 replacing 4620, a second of 80B40 replacing 4140) like experiences have been reported. In fact, no difficulties in the forging of boron steels have been encountered to my knowledge.



**Welding** is a process which is important in the fabrication of many steel products. The principal factors in weldability are carbon content and hardenability. These determine whether preheating, postheating or special techniques are necessary for sound welds, free from hard, brittle layers alongside the joint.

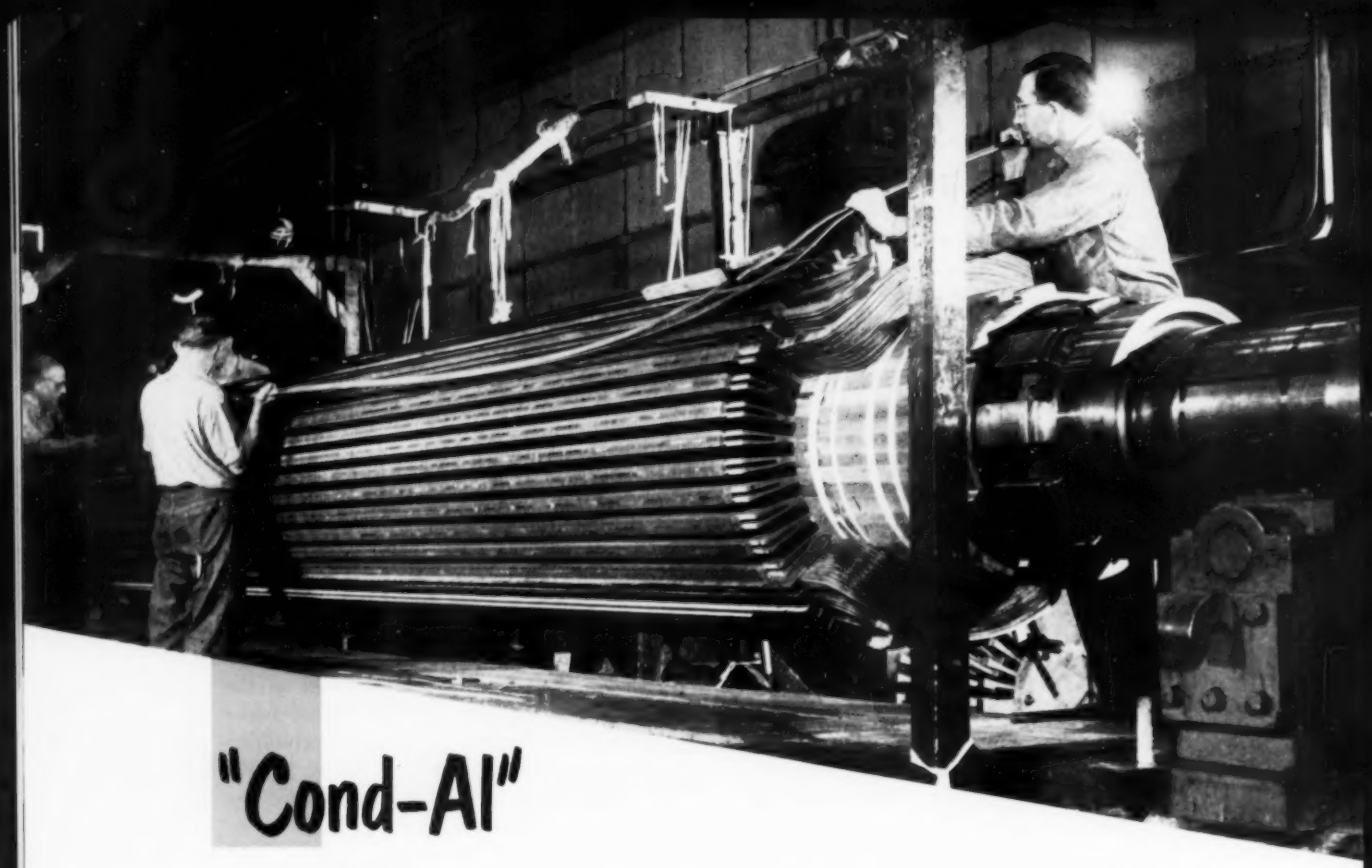
There is little information published on the welding of boron steels, although a considerable tonnage has been welded. Most of the tanks of World War II had boron steel armor of welded construction. Special techniques were required to produce sound welds, but the basic composition of alloy required this, not the boron "intensifier".

Another boron-treated plate steel, with 100,000-psi. yield strength after heat treatment, is welded without preheating or postheating. It has been used in the booms and buckets of large power shovels, in high-pressure vessels, and in other applications where a high-strength, weldable steel permits lighter weight.

T. G. Digges of the National Bureau of Standards has investigated the weldability of steels with 0.30 to 0.45% carbon and 0.80 to 1.60% manganese, with and without boron. He concluded that boron had no adverse effect on weldability. Since the boron steels in a given structure or machine are usually of lower alloy content than the steels they replace, they should be more easily welded.

**Conclusion** – We have reviewed the machinability, the cold and hot forming, and the welding of boron-treated steels in terms both of performance in industry and of laboratory testing programs. We have discussed the factors affecting performance in each step of processing in manufacture.

The evidence shows that the working of boron-treated steels in the shop should cause no more troubles than any new alloy steel. In most instances, experience with thousands of tons of boron-treated steels proves considerably better shop performance and economy than the higher alloy steels formerly used.



# "Cond-Al" — a Tailor-Made Aluminum Alloy of High Creep Strength and

DESIGNERS of rotating electrical machinery have long wished for a conductor material which is light in weight but which would still have high strength and high conductivity. Conductors with these characteristics are particularly desirable for field windings in generators driven by high-speed turbines. Conductivity grade aluminum has been used in the past because of its favorable ratio of weight to electrical conductivity; generator fields for operating at 3600 rpm. can be designed larger in diameter (and therefore greater in capacity) than is possible with copper windings.

Such conductors are placed in slots in the rotor forging, as shown in the headpiece of this article, and under certain operating conditions the compressive stresses produced by restrained expansion are sufficient to cause progressive plastic deformation in aluminum conductors of conventional "electrical conductivity" or E. C. grade, and a program to formulate a new aluminum alloy became desirable.

The goal was to produce a commercially available alloy with electrical conductivity close to that of E. C. aluminum but with greatly improved rupture and tensile properties, higher recrystallization temperature and resistance to compression creep at operating temperatures. If these properties could approach those of silver-bearing copper, the alternative high-strength conductor, so much the better. So the engineering staff placed an order on the research laboratory for such a new alloy.

**Research** – To develop a stronger aluminum, it was necessary to undertake a basic program of research to determine the effect of additions of single metals on the recrystallization, electrical conductivity, and rupture strength of "pure" aluminum. Various unalloyed aluminums described in the literature have electrical conductivities ranging from 63.5 to 65.4% of

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# Conductivity

that of the "International Annealed Copper Standard". A few references cite the effects of addition metals. Published reports on the effect of addition metals on the recrystallization and rupture strengths of aluminum appeared to be very limited at the time the research was started. Standard E. C. grade aluminum contains a minimum of 99.45% Al, with the chief impurities being 0.25 to 0.45% Fe and about 0.10% Si. Its electrical conductivity may range from 61.5 to 62.5%.

To secure the necessary basic information, the effects of the following eleven single addition metals on the base material (99.95% pure aluminum) were determined: 0.30% Ag, 0.30% Be, 0.20% Cr, 0.30% Cu, 1.00% Fe, 0.20% Mg, 0.05% Mn, 0.50% Ni, 1.00% Si, 0.05% Ti, and 0.50% Zr. These tests provided data on the following aspects:

1. As-cast fractures.
2. Cold workability and stiffness (wrought).
3. Recrystallization behavior and hardness in samples annealed in various cycles and then cold worked 60%.
4. Electrical conductivities for three conditions: 60% cold worked, annealed for 4 hr. at 750° F. (400° C.), and annealed for 10 hr. at 930° F. (500° C.).
5. Microstructures as cast and after annealing cold worked alloys for 10 hr. at 930° F. (500° C.).
6. Conventional rupture-life tests in two conditions: *(a)* annealed at 930° F. (500° C.) and *(b)* with 60% cold work.

The detailed results of this research have been previously published in a paper entitled "The Effect of Single Addition Metals on the Recrystallization, Electrical Conductivity and Rupture Strength of Pure Aluminum", by R. H. Harrington, *Transactions* ASM, Vol. 41, 1949, p. 443. Of the eleven addition metals, the individual alloying effects of Fe, Mg and Zr proved most important. For the most useful strength values the alloy must be cold worked; consequently the rupture strength and electrical conductivities in the cold worked condition are key factors, and representative values are shown in Table I. (The rupture tests for Mg and Zr were stopped at the indicated times *without* failure.) Since zirconium additions are difficult to control and lower the conductivity too far, magnesium stood out as a single addition metal to achieve the desired goal.

The second stage of the research was to make and test alloys of the following four compositions:

**Table I – Rupture Life and Conductivity of Alloys 60% Cold Reduced**

| Alloy | Rupture Life *(a)* | Conductivity *(b)* |
|---|---|---|
| 99.95% Al | 20 hr. | 64.1% |
| 0.30% Ag | 40 | 63.0 |
| 0.30% Be | 40 | 62.5 |
| 0.20% Cr | 40 | 50.2 |
| 0.30% Cu | 260 | 60.9 |
| 1.00% Fe | 340 | 60.8 |
| 0.20% Mg | >2960 *(c)* | 61.6 |
| 0.05% Mn | 20 | 58.6 |
| 0.50% Ni | 40 | 62.8 |
| 1.00% Si | 50 | *(d)* |
| 0.05% Ti | 40 | 62.2 |
| 0.50% Zr | >2040 *(c)* | 53.3 |

*(a)* At 255° F. (125° C.) under 10,500 psi. stress
*(b)* Per cent of international copper standard
*(c)* Test stopped without failure
*(d)* Samples unsatisfactory for test

| Alloy | Composition |
|---|---|
| A | 1.05% Fe, 0.32% Mg, bal. Al |
| B | 0.53% Fe, 0.29% Mg, bal. Al |
| C | 0.43% Fe, 0.32% Mg, 0.10% Si, bal. Al |
| D | 0.41% Fe, 0.005% Mg, 0.10% Si, bal. Al |

Since iron is beneficial in raising the recrystallization temperature and conferring a high rupture life in the *annealed* state, alloys A and B were designed to disclose the value of combining magnesium with iron. Alloy D is standard E. C. grade aluminum; alloy C results from adding 0.30% Mg to it. Although the magnesium and silicon contents of alloy C are too low to yield any major improvement by heat treatment (in the absence of cold work), it was hoped that aging of cold worked alloy C below its recrystallization range would harden

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## Creep Strength of Cond-Al

the metal. This matter had already been studied by the senior author; see "The Role of Strain in Precipitation Hardening", by R. H. Harrington, "ASM Symposium on the Age Hardening of Metals", 1940.

Stocks of these four alloys were treated as nearly identically as possible through the routine of casting the ingots, hot rolling above 750° F. (400° C.), annealing 4 hr. at 840° F. (450° C.), finish cold rolling by a 10% reduction, and final aging of 5 hr. at 390° F. (200° C) to stabilize the materials for subsequent use at temperatures up to 300° F. (150° C.).

Compression creep tests made in specially devised equipment showed that alloy A shortened 50% less (in the first 100 hr.) than alloy D, alloy B was a little better than alloy A, while alloy C shortened only about 10% as much as alloy D (E. C. aluminum). Electrical conductivities of all four were acceptable.

Eventually, alloy C was accepted as a new high-strength, low-creep, high-conductivity aluminum named "Cond-Al". U. S. Patent No. 2,572,562 was issued, and assigned by R. H. Harrington to General Electric Co. It was so outstanding in its resistance to creep that its other properties were compared to the old standard E. C. aluminum (alloy D). Table II shows that alloy C is markedly superior to D in what we call "useful strength" both at room temperature and at 285° F. (140° C.). Aging the cold worked alloy C at 390° F. (200° C.) results in the hoped-for useful age hardening, while E. C. aluminum (alloy D) definitely softens after the same treatment.

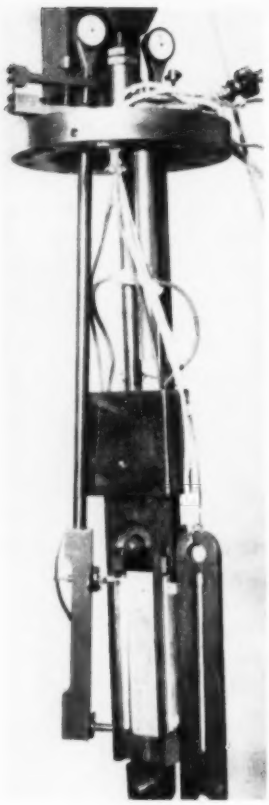


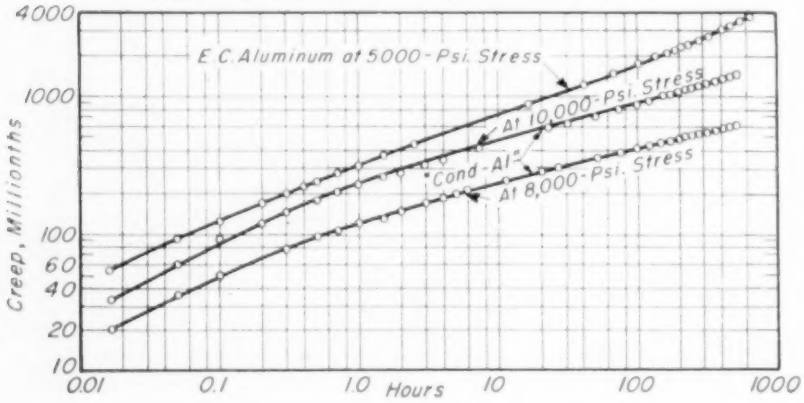
*Fig. 1 – Specimen String, Less Heating Furnace, for Measuring Creep in Compression*

**Compression Creep** – A new method of evaluating compression creep for new materials and for different lots of both aluminum and copper-base alloys has proven satisfactory over a period of about six years. Since this test first pointed out the advantages of Cond-Al, this cooperative development by the applied mechanics department of Union College (M. F. Sayre, professor) and the General Electric Co. merits a brief description here.

With but few exceptions, creep testing has been done under tensile stress. In this investigation it was desirable to use compressive stress in order to duplicate service conditions and avoid possible errors due to the Bauschinger effect (that phenomenon by which deformation of a metal raises the yield strength in the direction of plastic flow and decreases it in the opposite direction). The shape of the specimen to be used was determined by the use of generator winding or bus-bar material, ordinarily not over ⅜ in. thick. Accurate results were desired, even at low rates of creep, which pointed toward the use of relatively long gage lengths. The specimen size finally selected was 1 in. wide by $\frac{5}{16}$ in. thick by 5.5 in. over-all, using a 5-in. gage length.

A specimen of these dimensions would of course buckle unless carefully loaded and given lateral support. The exact details will be given in a later paper, but are indicated by Fig. 1. The specimen, shown in place near the bottom, is carefully machined to rectangular form and the ends are lapped. The side plates, which transmit the load from below to the top of the specimen, bear just sufficiently against the sides of the specimen to prevent the beginning of buckling without producing objectionable friction.

*Fig. 2 – Compression Creep in Micro-Inches per Inch of E. C. Aluminum and Cond-Al at 284° F. (140° C.)*



Tube-and-push-rod extensometers are mounted on each side of the specimen and reach through the slots in the supporting plates (the front plate is swung to the right and the front extensometer to the left in Fig. 1) so as to transmit the changes in length between gage points to dial indicators near the top of the photograph. These are graduated in ten-thousandths of an inch. A suitable tube furnace supports the upper flange and heats the sample to the chosen test temperature.

Sample charts for Cond-Al and for E. C. aluminum are given in Fig. 2. For quick check during this investigation, the total creep during the first 100 hr. of loading has been a good criterion of the relative merits of different batches, although most runs have been continued to 500 or 1000 hr.

### COMMERCIAL DEVELOPMENT

After the laboratory investigation, which indicated the possibility of obtaining very satisfactory results with small lots of material, commercial stocks of alloy C composition were obtained. The first lot of commercially alloyed and rolled Cond-Al was cold rolled 10% and aged 5 hr. at 390° F. (200° C.). Creep tests on this lot were very disappointing.

In the research program all hot work was carefully done above 750° F. (400° C.) and cold working warmed the stock to temperatures considerably below 400° F. It is generally unnecessary to control commercial rolling in this fashion. Inquiry as to the mill procedure in rolling this first lot elicited the following reply:

"We cast a 12x12 ingot which was then bloomed to a 6x6. This bloom was preheated at approximately 800° F., and at this starting temperature was roughed down and while still at a temperature of about 600° F. was passed over to a finish hot rolling mill which rolled it to the final size. The final properties are about ¼ hard, but no cold work was given. There were no intermediate anneals and the metal goes from a 6x6 bloom to the finished size in one general sequence."

It appeared from this account that the potential hardening phase ($Mg_2Si$) had been rendered ineffective by such a production routine. If such was the case, it could be restored by a proper heat treatment.

The program for a curative treatment was as follows: *(a)* three different solution treatments of 4 hr. at 840, 970 and 1040° F. (450, 520 and 560° C., respectively) with two rates of cooling (air and water quenching) from each; *(b)* each lot then cold rolled 10%; *(c)* subsequent aging of portions of each lot for 1 hr., 4 hr., and 20 hr., at each of the four aging temperatures, 255, 300, 345 and 390° F. (125, 150, 175 and 200° C., respectively).

Results were appraised by hardness (Rockwell H-scale readings). Hardnesses after solution treatments were as follows:

| Temperature | Time | Coolant | Hardness |
|---|---|---|---|
| 840° F. (450° C.) | 4 hr. | Air | H-38 |
| | | Water | H-46 |
| 970° F. (520° C.) | 4 hr. | Air | H-40 |
| | | Water | H-48 |

These materials all responded quite similarly to cold work followed by aging. For example, after 10% cold rolling the hardness was H-68. Aging 20 hr. at 255° F. (125° C.) increased this 8.5 points to H-76.5. Aging at 300 and 345° F. (150 and 175° C.) hardened the cold rolled material quickly — an increase of 8 to 10 points in 4 hr. Four points more could be had by extending the time to 20 hr. A temperature of 390° F. (200° C.) caused overaging in the sense that the hardness rose from H-68 to H-78 in 4 hr., but then fell to H-75.5 at 20 hr.

These figures show that the capacity to produce strain-induced age hardening is restored to commercial stock by proper solution treatment. Some results of such treatment on the creep of Cond-Al are indicated in Table III.

Subsequent tests showed that the solution temperature of 1040° F. (560° C.) gave the lowest creep. Present mill practice is to supply solution treated stock which is then cold rolled the desired amount and properly aged.

Some representative creep results from various commercial stocks of Cond-Al are shown graphically in Fig. 3. The lower band shows results for commercial E. C. aluminum. The upper band similarly shows range of creep

**Table II — Comparative Strength and Hardness**

| | Cond-Al | E. C. Grade |
|---|---|---|
| Yield strength* | | |
| at 70° F. (20° C.) | 18,100 psi. | 9,400 psi. |
| at 285° F. (140° C.) | 16,600 | 8,400 |
| Hardness (H scale) | | |
| Solution treated | 45 | 23 |
| Cold rolled 10%† | 76 | 60 |
| Aged at 390° F. (200° C.)‡ | 88 | 55 |

*0.2% offset
†Cold rolled after solution treatment
‡Aged after above treatment

results for commercial Cond-Al. The top curve is from creep data for laboratory treated single test specimens of commercial Cond-Al. Naturally, quenching a coil of Cond-Al stock gives a somewhat slower rate of cooling than if a single test piece is quenched. With further experience in the mill processing of Cond-Al it can be expected that the middle band will move upward toward the top curve for laboratory results.

In addition to high strength properties, conductivity, and thermal stability, some other physical properties of Cond-Al are as follows:

Fatigue strength at room temperature (fully treated): 10,000 psi. for 500 million cycles.

Thermal conductivity, K, in watts per sq.cm. per cm. per °C.:

| Temperature | K |
|---|---|
| 50° C. | 2.09 |
| 100° C. | 2.13 |
| 150° C. | 2.17 |
| 200° C. | 2.21 |

Electrical conductivity may range from 58.5 to 60% of copper standard.

Temperature coefficient of resistance (same as value for copper) — 0.00385 ohm per ohm per °C. between 25 and 144° C.

Coefficient of linear thermal expansion:

| Temperature Range | Coefficient of Expansion |
|---|---|
| 20 to 120° C. | $23.6 \times 10^{-6}$ in. per in. per °C. |
| 20 to 220° C. | $24.6 \times 10^{-6}$ |

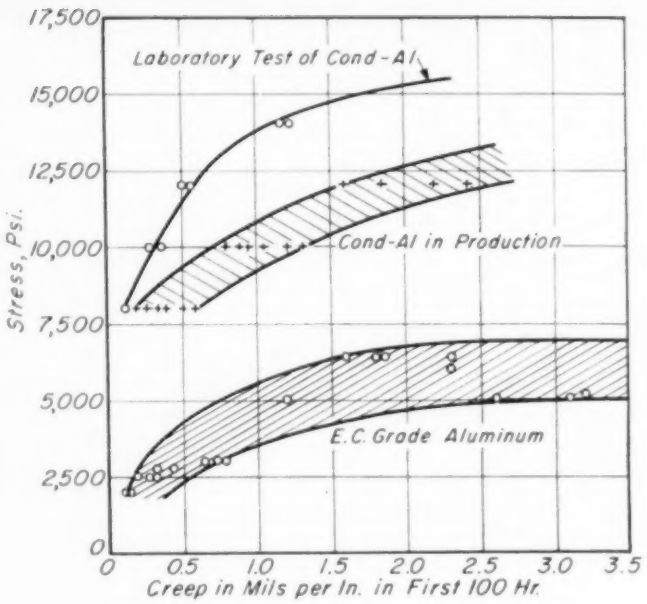



*Fig. 3 — Range of Values of Creep Tests at 284° F. (140° C.) of E. C. Grade Aluminum, Cond-Al in Production, and a Laboratory Run of the Latter*

## APPLICATIONS

Cond-Al has been used in the aged condition for turbine-generator field windings since 1949.

**Table III — Creep in Compression of Commercial Alloy Stressed 8000 Psi. at 284° F. (140° C.)**

| Solution Temperature | Coolant | Aging Treatment | Creep* |
|---|---|---|---|
| 840° F. (450° C.) | Air | 20 hr. 345° F. | 900 |
| 840° F. (450° C.) | Water | 20 hr. 345° F. | 755 |
| 970° F. (520° C.) | Air | 20 hr. 345° F. | 594 |
| 970° F. (520° C.) | Water | 20 hr. 345° F. | 410 |
| 840° F. (450° C.) | Air | 4 hr. 390° F. | 1350 |

*Micro-inches per inch in the first 100 hr.

As of this writing, there have been 18 machines so wound. Typical is the one shown during assembly in a rotor forging in the view at the head of this article.

Its utility thus far has not been so much a substitute for copper windings as a new metallic alloy permitting the engineer to design larger units than could be built using copper conductors. For example, the new units for Electric Energy, Inc., at Joppa, Ill., have Cond-Al field windings. These are the highest rated 3600-rpm. turbine generators in the world (216,000 kva.). The use of Cond-Al and conventional ventilation methods enabled us to meet relatively short delivery dates for these very large machines. More than a dozen other generators, similarly rated, are now on order, and all will have Cond-Al field windings.

Its excellent mechanical properties, which have been obtained while maintaining high electrical conductivity, also make it very attractive for other applications such as wire, cable, and busbars.

The story of Cond-Al, then, to date is one of the cooperative efforts of many, who have created this new alloy, developed it, and applied it to commercial practice in a relatively short time. It is the story of a planned invention through the joint efforts of General Electric men in the Research and Works Laboratories and the Engineering Staff.

# Ultra High-Strength Steels

THE SOUTHERN CALIFORNIA Section of the Society of Automotive Engineers presented a seminar on ultra high-strength steels in aircraft applications during the Western Metal Congress in Los Angeles in March. Excellent cooperation by the American Society for Metals and the University of California (Los Angeles) also aided in achieving the splendid attendance and interest which were manifested at each of the three sessions. The purpose of the seminar was to present information regarding metallurgy, processing and design considerations of steels heat treated above 200,000 psi. A summary of the principal conclusions will be attempted.

Speakers for the first session on alloy compositions, grain size, hardenability, and other metallurgical characteristics were Cyril Wells of Carnegie Institute of Technology, J. M. Hodge of United States Steel Corp., and L. L. Ferrall of Crucible Steel Co. of America.

**Influence of Carbon** – Alloy compositions for these steels have been designed to include just slightly more than the minimum carbon content necessary to produce the required tensile strength, and sufficient alloys for hardenability. This means a composition of 0.25 to 0.33% carbon and varying amounts of manganese, silicon, chromium, molybdenum, nickel, vanadium and boron, depending on their specific influence and their action in combination with others present.

**Mechanical Properties** were presented on A.I.S.I. 8740, 8745, 4330, 4340, "HyTuf" (0.25 C, 1.35 Mn, 1.50 Si, 2.0 Ni, 0.40 Mo), "Super HyTuf" (0.40 C, 1.5 Mn, 1.9 Si, 1.4 Cr, 0.25 V, 0.30 Mo), and special laboratory heats of other variants tempered in the 400 to 600° F. range. In this tempering range steels containing 1.5 to 3.0% silicon exhibited good toughness; the ductility of lower carbon martensite was much higher than had been anticipated.

Best mechanical properties were obtained when the structure was approximately 100% martensite; water quenching, however, often cracked the specimen.

The notch sensitivity of "Super HyTuf" appeared to be considerably less than that of A.I.S.I. 4340 at the 270,000-psi. level; however, a double tempering was advised for steels with more than 0.33% carbon to improve toughness.

Data presented in the second session seemed to show that additions of aluminum and silicon reduced brittleness after heating in the 400 to 600° F. tempering range. A considerable body of corridor-expressed opinion was also to the effect that, in addition to the silicon, a little vanadium would further aid in reducing the notch sensitivity of these steels.

At 60° to the direction of rolling or forging grain, a large reduction in yield was evident, as well as lower ductility in the transverse direction.

It was emphasized throughout these discussions that the primary consideration for optimum performance at the very high tensile levels of 260,000 to 300,000 psi. was to hold the carbon content to a minimum and obtain properly tempered martensite.

### PROCESSING OF HIGH-STRENGTH STEELS

Speakers for the second session on processing methods were J. W. Sands of International Nickel Co., C. E. Moeller of Menasco Mfg. Co., and G. G. Wald of Lockheed Aircraft Corp. They presented data relating to fabricating, heat treating and finishing operations as performed by the consumers of these ultra high-strength steels.

**Welding and Joining** – Experience in flash and fusion welding has shown that at 260,000-psi. strength levels more specimens fail in the weld area than would be expected in specimens heat treated to lower tensile levels. To improve this condition it was recommended that all undercuts and weld deposits be ground off flush and the areas polished.

**Specialized Heat Treatments** – Experimental studies indicate that if quenched parts are frozen in liquid nitrogen, the ultimate tensile and the yield strengths are improved without much change in ductility figures (when tested at room temperature). It is believed that this

**Reported by A. A. BIBEE**
**Supervisor, Materials and Processes**
**El Segundo Division**
**Douglas Aircraft Co., Inc.**
**El Segundo, Calif.**

operation prevents the stabilization of the retained austenite after normal quenching.

Another interesting suggestion for straightening warped parts was to clamp them in a jig and re-temper. When straightening must be performed, this operation should be followed by stress-relieving at 375° F. and shot-peening. Warpage may and should be minimized, of course, by careful quenching techniques and temperature control.

In the third session it was emphasized that optimum heat treating processes must be determined so that realistic allowables can be established and then rigidly maintained. Decarburization must be kept at a minimum since in the 260,000 to 280,000-psi. range the likelihood of fatigue failure is much greater below 50,000 cycles than at the 200,000-psi. level.

**Grinding, Machining and Shot-Peening** – It was recommended that 0.030 in. of material be left on machined parts for clean-up. Holes should be tapped to size and retapped with high speed steel after the part has been heat treated. Tapped holes on the order of ⅜ in. diameter, however, should be avoided.

As much machining as possible should be performed *before* heat treating. This is important since it is very difficult to maintain accurately tool set-ups when working hardened steel. One speaker at the third session estimated that a tool Rockwell C-75 hard would lose 0.001 in. from the tip on each pass.

Best results in grinding have been obtained by removing 0.001 in. of material with each pass, followed by shot-peening to remove detrimental surface effects. It was predicted that more of these parts will be shot-peened to produce compression of the surface layers (0.006 in. in depth) and to minimize effects of surface imperfections and decarburization.

*Fig. 1 – A HyTuf Forging Weighing 1150 Lb. Represents the Type of Airframe Components Which Utilize Ultra High-Strength Steels*

**Cleaning and Plating** – Specialized cleaning procedures must be used for satisfactory plating and to minimize embrittlement. These will include shot-peening prior to plating, and anodic cleaning following cathodic cleaning.

## DESIGN CONSIDERATIONS

The final session of this excellent program at the Western Metal Congress, covering design considerations for aircraft use of ultra high-strength steels, was held on the campus of the University of California (Los Angeles). The speakers were D. A. Redwine of Consolidated Vultee Aircraft, M. A. Melcon of Lockheed Aircraft Corp., and R. E. Greenough of Cleveland Pneumatic Tool Co. The session was opened by posing four questions:

1. What is "high heat treat" steel?
2. What advantages are gained by using it?
3. Should the aircraft industry use it?
4. What precautions should be taken when it is used?

Answers to these questions were given and enlarged upon by stating that:

1. "High heat treat" steels now available for use in aircraft design are "Super HyTuf", "Super TN-2" and A.I.S.I. 4340 heat treated to 256,000 to 283,000 psi. (Rockwell C-50 to 53). (Composition of "Super TN-2" is 0.38 to 0.43 C, 0.7 to 1.0 Mn, 0.5 to 0.7 Si, 1.30 to 1.60 Cr, 2.0 to 2.4 Ni, 0.4 to 0.6 Mo.)

2. Advantages in using these steels were summed up as follows:

*(a)* Weight and space saving.

*(b)* Existing inspection techniques may be used to determine the quality of the parts produced.

*(c)* Machining techniques have been established (with the exception of broaching).

*(d)* Steel producers have the ability and facilities to make these steels.

Some disadvantages were mentioned:

*(a)* There is no service experience with these new metals.

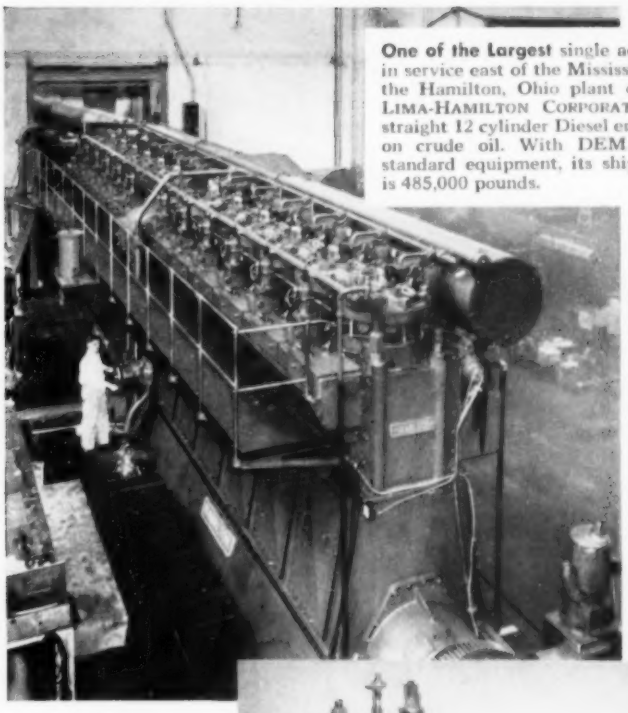
*(b)* They involve greater deflection and secondary moments.

*(c)* They cause high tool wear and need heavier machinery.

*(d)* They require more stress-relieving heat treatments.

3. Why should the aircraft industry use "high heat treat" steel?

*(Continued on p. 167)*



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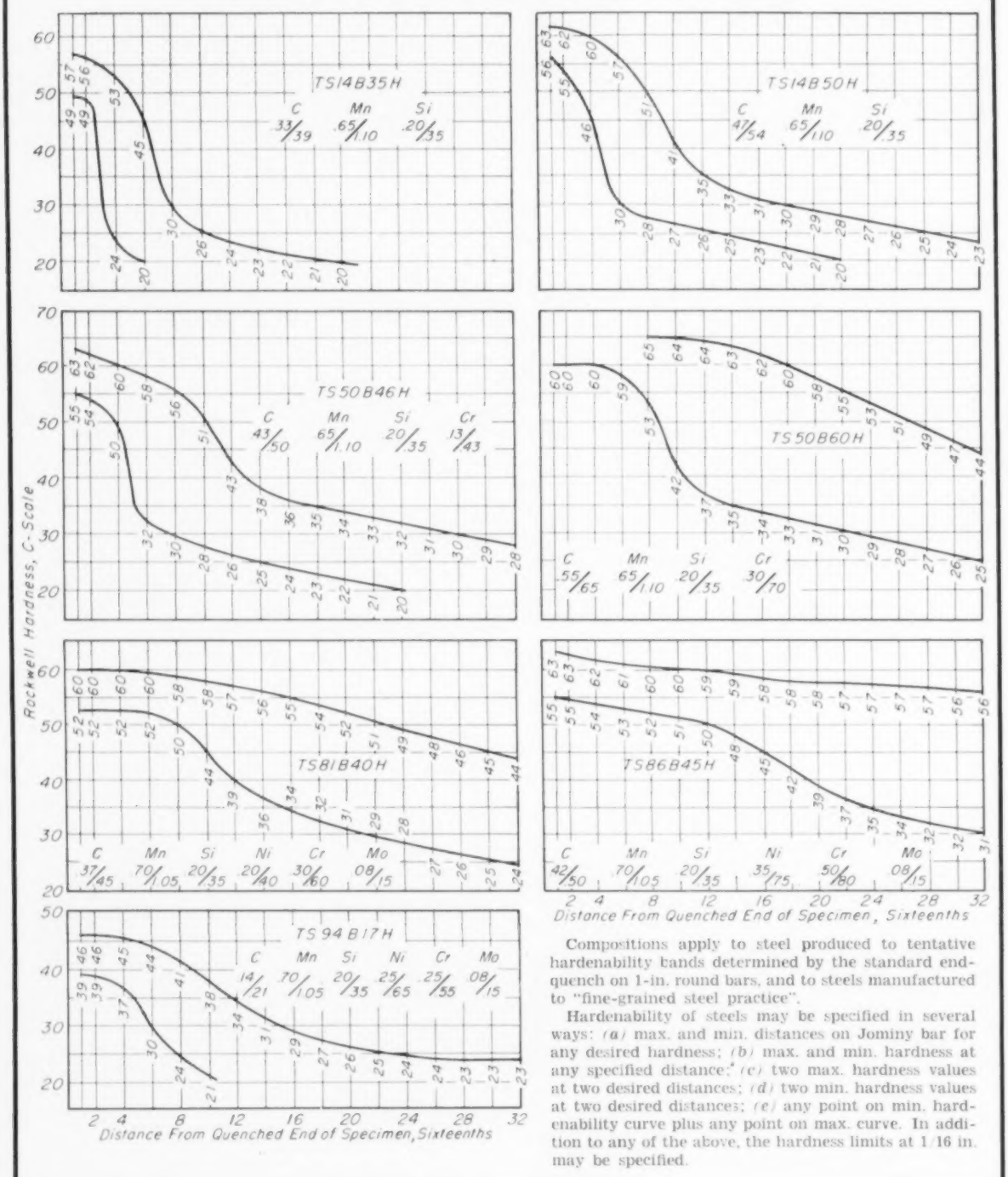
# Tentative Hardenability Bands for Boron Steels

*Adopted September 1952 by American Iron & Steel Institute*




Compositions apply to steel produced to tentative hardenability bands determined by the standard end-quench on 1-in. round bars, and to steels manufactured to "fine-grained steel practice".

Hardenability of steels may be specified in several ways: *(a)* max. and min. distances on Jominy bar for any desired hardness; *(b)* max. and min. hardness at any specified distance; *(c)* two max. hardness values at two desired distances; *(d)* two min. hardness values at two desired distances; *(e)* any point on min. hardenability curve plus any point on max. curve. In addition to any of the above, the hardness limits at 1/16 in. may be specified.

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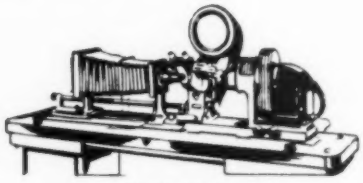

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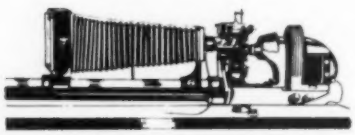

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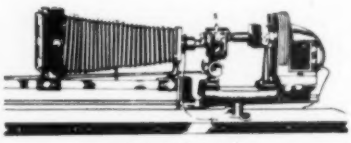

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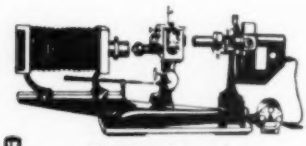

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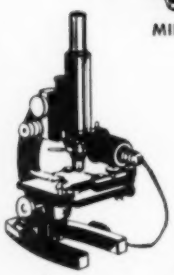

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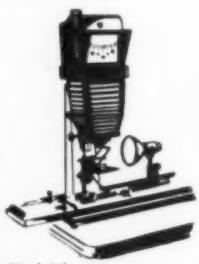

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By E. T. HAYES* and W. W. STEPHENS*, U. S. Bureau of Mines, Region II, Albany, Ore.

*Mr. Hayes is chief of the physical metallurgy branch. Mr. Stephens (now metallurgist with Carborundum Metals Co. of Akron, N. Y.) was until recently chief of the rare metals branch at Albany, Ore.

# The Metallurgy of Zirconium

METALS generally classified as uncommon or rare are beginning to play increasingly important roles in the fast-moving technological developments of today. Many of them are rare or uncommon not in the sense that they don't occur abundantly in the earth's crust, but rather that their extraction from their ores is very difficult. Many of them have unique and useful properties but have not been commercialized because of the difficulty and expense of producing them in a useful state. Indeed, the true properties of many of these have been known for only a short time, even though their existence as elements has been known for more than a hundred years.

An outstanding example is zirconium, whose desirable properties to the nuclear energy program have been outlined by E. C. Miller in the leading article in this issue of *Metal Progress*. Even here it is worthy of note that the use of zirconium in quantity (and its interest to peacetime industry) primarily results from a process which can produce ductile metal in reasonable quantities at a cost far below that of previously available methods. It is also fortunate that the metal and its compounds are nontoxic and entirely safe to handle at high temperatures or as finely divided particles, provided only that the ordinary and reasonable precautions are taken against dust and fume. Zirconium, while lacking the attributes to make as spectacular a debut as its sister, titanium, is certainly in a position to rival any of the other uncommon metals as a structurally useful metal.

**Historical Outline** — The first practical method for producing ductile zirconium was developed in 1925 by Van Arkel, DeBoer and Fast at the University of Leyden and the Philips Lamp Works at Eindhoven, Holland. Their method, commonly known as the iodide process, depends on the decomposition of zirconium iodide by a hot wire or filament. The first commercial production of ductile metal in the United States was undertaken about 15 years ago by the Foote Mineral Co., using the iodide process. The initial selling price of this metal was reputed to be $650 per lb. Concurrently, W. J. Kroll and co-workers at the Northwest Electrodevelopment Laboratory of the U. S. Bureau of Mines at Albany, Ore., started investigations of cheaper methods and chose a process based on reduction of the tetrachloride by molten magnesium in an inert atmosphere, similar to the familiar Kroll process for titanium. Success was announced early in 1946.

This was the state of zirconium production technology when the atomic scientists began to concern themselves with power-producing reactors. Here, the basic problem is one of operating the reactors at a considerably higher temperature than attained in the plutonium-producing reactors at Hanford, Wash. Aluminum is used for such components as water tubes in the Hanford reactors because of the requirement for low neutron absorption. However, at higher temperatures aluminum has poor corrosion resistance. Other conventional

materials cannot be used because they absorb too many neutrons, but it was found that pure zirconium has acceptable neutron absorption characteristics as well as promising mechanical properties and corrosion resistance.

This development has given great impetus to all phases of zirconium chemistry and metallurgy. One problem which has received much attention is the separation of the hafnium contained in zirconium ores to the extent of 1 to 3%. Fragmentary information on a number of separation processes has been published recently, but since they are all chemical or physico-chemical they will not be described in detail here. [See the article by Mr. Miller on p. 67.] The product usually is zirconium oxide or oxychloride of low hafnium content which is then used as the starting material for production of metal. It is an interesting possibility that this work may result in the availability of appreciable quantities of hafnium for peacetime applications; chemically it is so close to zirconium that one should be able to predict its alloying and physical properties with a pretty fair degree of accuracy.

Demands from the Atomic Energy Commission have resulted in rapid expansion of production facilities by both the Kroll and the iodide process. The price of iodide zirconium has steadily decreased due to this increased production capacity and it is now quoted at $70 per lb. in quantities of 100 lb. or over.

To date, a large portion of the production has been in government-owned facilities, but the Atomic Energy Commission has contracted with at least one commercial producer for 150,000 lb. of hafnium-free zirconium per year.

**Occurrence of Ores** – Zirconium is the ninth most abundant metal; it is more abundant than nickel, copper, zinc, or lead. The principal ore* is the silicate, zircon, which occurs widely distributed in beach sands of Australia, India, Africa, and North and South America. In the United States, the sands on ancient beaches in Florida supply the major portion of the commercial requirements. Astronomical quantities are readily available. Here, zircon is concentrated with the titanium minerals ilmenite and rutile and the phosphate of the rare earths, monazite. It is reported that large quantities of zircon are being stockpiled as the result of increased demand for titanium.

Domestic zircon consumption, used principally in the production of ceramics, refractories, and chemicals for leather tanning, is estimated between 20,000 and 30,000 tons annually. The ore reserves in the United States are conservatively estimated at 2½ million tons of contained zirconium. Zircon concentrates (65% $ZrO_2$) are now quoted at $40 per ton or approximately 4¢ per lb. of contained metal. The high cost of the metal is not due to a high-cost ore.

### PRODUCTION OF METAL FROM ORE

Production of ductile zirconium is a tedious and expensive process because of the highly reactive nature of the element. This high reactivity manifests itself in the refractory nature of zirconium ores and compounds and in the tendency for metallic zirconium to react with the common gases at elevated temperatures and to reduce the ordinary refractory oxides of aluminum, silicon or calcium at or below its melting point. Zirconium not only oxidizes and nitrides readily at high temperatures, but the oxides and nitrides rapidly diffuse into the metal above the transformation temperature of 1585° F. (863° C.) making it hard and brittle. As little as 0.2% oxygen in the metal is enough to impair its ductility. It is apparent, then, that any successful reduction process must exclude the common gases by operating either in some inert atmosphere or in a vacuum. The high melting point of the metal (3360° F. or 1850° C.) and its ability to reduce refractory oxides discourage one from attempting the traditional smelting or melting techniques.

Many approaches to the problem of producing ductile metal have been tried, most of which are included in the following outline:

1. Reduction methods
   - A. Reduction of oxides
   - B. Reduction of halides
2. Electrolytic methods
   - A. Fused salt electrolytes
   - B. Aqueous electrolytes
   - C. Organic electrolytes
3. Thermal dissociation methods
   - A. Hot filament or tube
   - B. Arc or molten metal

**Reduction Methods** – Compounds of zirconium which are suitable for direct reduction include the oxide, chloride, fluoride, double alkali chlorides, and double alkali fluorides. Most of these may be reduced by one of several reagents to yield metal of fairly high purity.

*See "Zirconium Ores", by O. C. Ralston, one of the contributions to the ASM Symposium on Zirconium held at Los Angeles the last week in March. The proceedings of these meetings will be published by the Society in book form during the summer.

*Fig. 1 — Container for Crude Zirconium Chloride With Floating Top and Coils Suspended Above. (Shelton and Dilling)*

The high reactivity and sensitivity of zirconium to the effects of contaminating elements, however, pose special problems in any process for usefully ductile metal.

In the first place, the compound to be reduced and the reductant must be obtainable in a *pure* state, since most of the impurities contained in either will be found later as contaminants. Secondly, the products of the reaction, including excess reagent, must be easily removed from the product. Third, the reductant must be sufficiently more active than zirconium to drive the reaction to completion and must not form alloys or compounds with the reduced metal.

In addition to these formidable requirements, it is desirable to produce metallic particles as large as possible to minimize contamination during subsequent handling. From the economic standpoint, one must consider not only the cost of the starting material and of the reducing agent but also the efficiency of the process plus costs of labor, equipment, power, overhead and profit.

Let us consider briefly various reducers: Reduction of the oxide with carbon or zirconium carbide leads to metal contaminated with oxide and carbide even when performed in a good vacuum at temperatures approaching 2500° C. (4500° F.). Aluminum offers little promise as a reducer because it is so difficult to remove it from the zirconium-aluminum alloy which is formed. Magnesium reduction of the oxide leads to difficulties in separation of the products because of the high melting point and low solubility of magnesium oxide. Calcium apparently is the only readily available metal suitable for reducing the oxide, and it has received considerable attention.

It may be noted that metal produced in this way is not as ductile as that produced by either the Kroll process about to be described or the iodide process, due to the difficulty in driving the oxygen low enough even by multiple reductions with a large excess of calcium. Distilled calcium must be used to avoid nitrogen contamination and the process must be carried out in a bomb due to the high vapor pressure of calcium at the reaction temperature.

**Kroll Process*** — The most successful commercial process, like the one for titanium, is distinctly a development of the Bureau of Mines' laboratories. W. J. Kroll worked at the Bureau's Northwest Electrodevelopment Laboratory from 1945 to 1950 and in these years the process named for him was used to produce zirconium, first in 90-g. batches, and later in 60-lb. batches (November 1947) and eventually 150-lb. lots in 1949.

To meet requirements of the Atomic Energy Commission the purity is now far above that of the metal produced in 1945 to 1949. As has already been stated, the principal impurity is hafnium, and the development of a chemical process to separate zirconium from hafnium which is continuous and workable (as contrasted with the laborious phosphate crystallization method) is one of the great chemical triumphs of the last decade. It was perfected by scientists with Carbide and Carbon Chemicals Co., operating at the Oak Ridge National Laboratory in Tennessee. The full details of this process are still classified [see p. 73 and 74 of Mr. Miller's article].

Hafnium-free zirconium oxide is calcined and mixed with lampblack, briquetted, and charged into a shaft resistor furnace about 26 in. in diameter and lined with silica brick. Electrical current is applied and the charge is heated to 1100 to 1500° F. (600 to 800° C.) by its own resistance, whereupon chlorine is fed to the bottom of the furnace. Zirconium chloride is formed, a gas which is condensed in a

*An extended discussion was presented to the ⊕ Symposium on Zirconium by S. M. Shelton and E. Don Dilling ("The Manufacture of Zirconium Sponge").

*Fig. 2 – Floating Top Loaded With Distilled Zirconium Chloride Suspended Above Baffle and Reduction Crucible Containing Magnesium. (Shelton and Dilling)*

nickel-lined chamber held at 355° F. (180° C.). Some impurities, such as silicon and titanium, which have chlorides that boil below this temperature can be effectively removed by proper condensation control.

In the actual reduction of the chloride, some 450 to 500 lb. of raw zirconium chloride is charged on trays into a steel container and placed in the bottom of a pit furnace, approximately 30 in. in diameter and 6 ft. deep. The furnace is evacuated with a water aspirator and back-filled with hydrogen. The raw zirconium chloride is then heated by radiation from heaters around the inner walls of the furnace and sublimes on air-cooled coils suspended from a floating lid on the top of the furnace (Fig. 1). The hydrogen serves to reduce any ferric chloride present to ferrous chloride (which has a high sublimation temperature); frequent bleeding of the system also removes a number of gaseous impurities.

The floating top and its coil containing some 450 lb. of dense purified chloride are then lifted from the retort and a stoichiometric amount of magnesium plus 20% excess is placed in another steel container (the "crucible") and set in the bottom of the furnace. (This assembly is shown in Fig. 2.) The lid plus the chloride is then returned to the furnace; the top is closed with a floating lead seal to compensate for pressure variations, the air is evacuated from the system once more, and the chamber back-filled with helium. The crucible of magnesium at the bottom of the furnace is heated to some 1550° F. (850° C.) and the coil area containing the chloride is heated above 625° F. (330° C.). The zirconium chloride sublimes and travels over the surface of the molten magnesium to produce magnesium chloride and zirconium metal.

After the reaction has finished and the furnace has cooled, the crucible is removed and inverted in a vacuum retort. Magnesium chloride and residual unreacted magnesium are distilled off in a vacuum of 50 microns or less at a temperature of about 1650° F. (900° C.). (See Fig. 3.) This is borderline temperature for complete removal of residual $MgCl_2$ and it would be better done at 100 to 200° F. higher, but higher temperatures are limited by the zirconium-iron eutectic (of about 16% iron) which melts at 1715° F. (934° C.). Titanium producers are more fortunate in this respect – the titanium-iron eutectic melts above 1000° C.

About 150 lb. of zirconium "sponge" per batch is produced by this process. It is separated from the iron crucible by a hydraulic press and chisel, and then separated into various grades. The material lying next to the reduction pot proper is rather high in iron; it must be segregated and blended to maintain a desired iron content in the product. Over 60% of the sponge is quite dense and does not have the low-density cellular characteristics of normal titanium sponge. After separation into various grades of material, the pieces are further broken up with a hydraulic press and chisel arrangement and then crushed to ¼ in. The crushed material is analyzed in 50 to 100-lb. lots and then blended into 2000-lb. lots of the desired specifications. A typical analysis of Kroll process zirconium in parts per million is as follows:

| | | |
|---|---|---|
| Chemical: | $N_2$ | 50 ppm. |
| | Mg | 800 or 0.08% |
| | Cl | 100 |
| Spectrographic: | Al | 10 ppm. |
| | Cu | 30 |
| | Pb | 30 |
| | Cr | 5 |
| | Fe | 300 |
| | Mn | 20 |
| | Ni | 2 |
| | Si | 20 |
| | B | 0.2 |
| | Hf | 82 |

*Fig. 3 – Components of the Furnace for Distilling Magnesium and Magnesium Chloride Out of the Zirconium Sponge. A water-jacketed vacuum chamber projects downward through the ceiling; it also extends upward into a larger heating furnace on floor above. (Note the vacuum pumps behind workman at left.) The inverted crucible full of zirconium sponge has already been placed in this chamber and rests on top of the vertical column. At eye level is a conical salt can in which Mg and $MgCl_2$ fumes will be condensed; below them are horizontal baffles to protect the vacuum connection. The workmen are about to place a circular sheath around this assembly and it will be pushed up by hydraulic ram into the chamber above and sealed tight. (Shelton and Dilling)*

These impurities add up to about 2650 parts per million or 0.265%, indicating that the sponge is 99.73% pure.

**Electrolytic Methods** – A number of investigators have attempted to deposit zirconium from aqueous or organic electrolytes operating at or near room temperature. A few have deposited thin films of zirconium-bearing material but none have succeeded in producing anything approaching a recoverable deposit of ductile metal. The probability of a commercial process based on these approaches seems to be remote.

Zirconium can be obtained by the electrolysis of a number of fused salt baths containing zirconium halides or double halides with or without the addition of zirconium oxide. In all electrolyses where the metal is produced at temperatures below its melting point, the cathode deposit consists of loosely joined crystals of metal or dendrites with large quantities of entrapped electrolyte. Until recently, none of the reported attempts have produced metal by electrolysis of fused salts which has subsequently yielded a ductile product.

Two recent investigations have resulted in development of methods which show promise along this line. Deposition of metal from a fused sodium chloride bath containing $K_2ZrF_6$ (Fig. 5) and operating in an atmosphere of purified argon* has resulted in production of fairly large crystals of zirconium which can be separated from entrapped electrolyte by leaching and then be melted to produce ductile metal. Another process using an all-chloride bath is also reported to have shown promising results. Operation in a controlled atmosphere, which is apparently a requisite to success, leads to difficulties in feeding the cell and removing the product. Unless something can be done to overcome these difficulties, operation of the cells cannot be continuous, as would probably be necessary for commercial production. Likewise, the cathode deposit now needs expensive intermediate treatment before the metal can be melted; entrapped electrolyte must also be recovered for economy. An electrolytic method for making a compact cathode deposit continuously would, therefore, represent a further and large advance.

**Thermal Dissociation Methods** – The best-known process of this type for refining impure metal (and the only one in commercial use) is the so-called "iodide process" developed by Van Arkel, DeBoer, and Fast which is used by the Foote Mineral Co. in this country and

*For a full discussion see "The Extractive Metallurgy of Zirconium by the Electrolysis of Fused Salts", by M. A. Steinberg, M. E. Sibert and E. Wainer, a paper in the Symposium on Zirconium.

*Fig. 4 — Blending Wheel for Crushed Zirconium Sponge*

by Philips Lamp Works in Eindhoven, Holland. This process has also been used by Westinghouse to refine metal for the A.E.C.

The starting material for the iodide process is generally crude zirconium powder or sponge produced by reduction of the oxide with calcium or magnesium, by the reduction of the tetrachloride with magnesium or sodium, or by the reduction of potassium fluozirconate with potassium.

The original equipment consisted of a cylindrical pyrex glass bulb connected to a vacuum system and equipped with electrodes which support a tungsten or zirconium filament. A perforated molybdenum cylinder was placed along the axis of the bulb and the narrow annular space between it and the inside wall of the bulb filled with crude zirconium. After introducing a small quantity of iodine, the bulb was evacuated to about $10^{-4}$ mm. of mercury and heated externally to a temperature of approximately 300° C., while the filament was heated to 1400° C. by its own resistance to passage of an electric current.

The iodine vapor formed within the bulb reacts with zirconium to form zirconium tetra-iodide vapor which dissociates on the hot filament, depositing zirconium as a growing crystal, and freeing the iodine which then reacts with more crude metal in the cooler zone of the vessel. In this process, voltage across the filament must be decreased and the current increased continuously as the deposited rod grows in order to maintain it at the required temperature. Thus an extremely flexible power source is required and the maximum attainable diameter of the rod is limited by the high current required at the end — in the neighborhood of 1000 amp.

The principal improvement in the commercial development of this process has been the substitution of equipment constructed of Inconel or other corrosion resistant alloys for glass. Units as large as 24 in. in diameter which produce rods about 1 in. diameter have been operated (Fig. 6 and 7). The heat radiated to the wall of the vessel necessitates cooling the outside with a circulating salt bath. Temperature of the crude metal must be held to about 300° C. (575° F.); otherwise, the less volatile lower iodides of zirconium are formed and deposition ceases. This places an obvious limitation on the size of deposits which may be grown in equipment of the present type. A possible improvement would be to separate the iodination and deposition steps of the process, but suitable equipment for such a scheme presents considerable difficulties.

The iodide process is essentially a refining process; it requires metallic zirconium as a starting material. The substitution of less expensive starting materials would be desirable. Investigations along this line are reported to be in progress.

The purity of the refined metal depends to a considerable extent on the purity of the crude from which it is made, since a portion of the contaminating elements is carried over

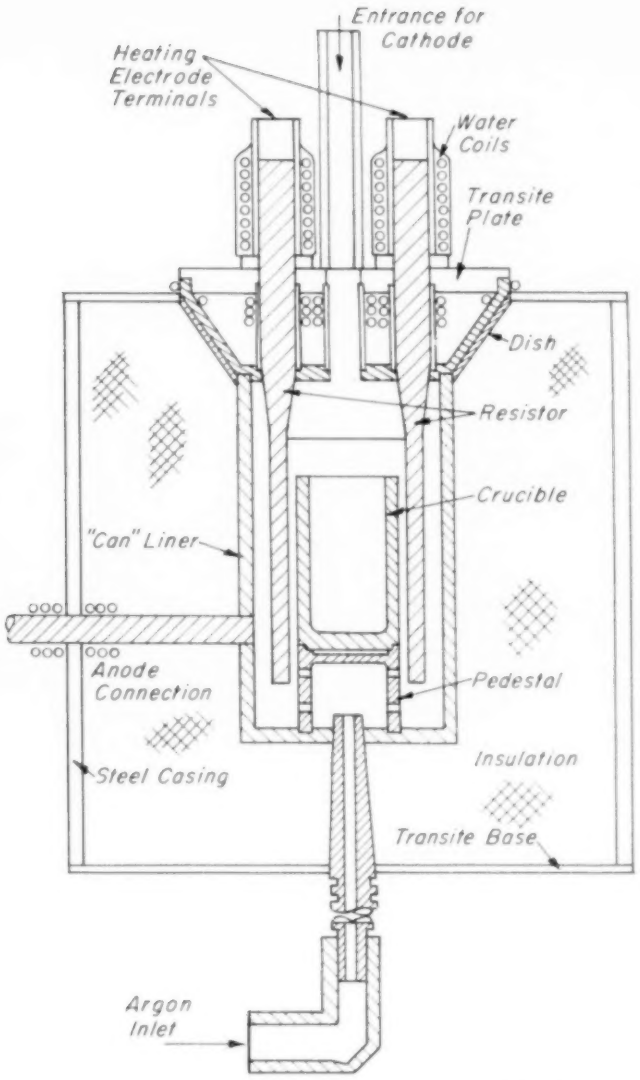



*Fig. 5 – Furnace Wherein Massive Zirconium Was Produced by Electrolysis of $NaCl$-$K_2ZrF_6$. Hatched portions are of purified carbon. (Steinberg, Sibert and Wainer)*

## Elimination of Impurities

with the zirconium.* F. B. Litton has recently reported (*Metal Progress*, December 1951, p. 83) that the average elimination of major metallic impurities is as follows:

| | |
|---|---|
| Silicon | 31.6% eliminated |
| Aluminum | 62.7% |
| Iron | 87.1% |
| Magnesium | 91.0% |
| Titanium | 48.0% |
| Nickel | None |
| Calcium | 34.2% |
| Hafnium | None |

When operating in metal equipment, the bar may actually contain more metallic impurities like chromium and nickel than the feed material, due to attack on the vessel. Iron, aluminum, and silicon may be carried over and deposited on cooler parts of the filament near the electrodes. Oxides and nitrides in the crude metal are not appreciably attacked by the iodine and the metal is effectively purified of oxygen and nitrogen, thus resulting in an extremely ductile metal.

The following analysis of standard zirconium crystal bar is by Litton:

| | | | |
|---|---|---|---|
| Si | 0.01% | Ca | 0.01 |
| Al | 0.01 | Cu | <0.01 |
| Mg | <0.003 | Ti | 0.03 |
| Pb | <0.001 | W | <0.001 |
| Mn | <0.001 | Hf | 2.40 |
| Cr | 0.001 | C | <0.001 |
| Sn | <0.001 | $O_2$ | <0.01 |
| Fe | 0.04 | $N_2$ | <0.01 |
| Ni | 0.01 | $H_2$ | <0.02 |
| Mo | <0.001 | | |

Not counting the 2.40% hafnium, the "purity" of the bar is about 99.83%.

**Melting** – Another perverse feature of zirconium is apparent in melting. When molten, it attacks practically every common crucible material known to man – in fact, a great number of uncommon ones which have been designed for the sole purpose of containing it. The first few thousand pounds of metal produced by the Kroll process was melted at the Bureau of Mines at Albany, Ore., in dense graphite in vacuum, and it was heated either by induction methods or by a split graphite resistor. Unlike titanium (which dissolves carbon as a function of time and temperature and attains as high as 2% at the normal pouring temperature of 3500° F.), zirconium picks up a maximum of 0.3 to 0.4% carbon, which for many normal uses would be satisfactory. However, due to strict purity requirements imposed by the nuclear projects, the use of graphite crucibles has been discontinued except for laboratory development work.

Several thousand pounds of Kroll process sponge have been melted in water-cooled crucibles using tungsten-tip electrodes; when melting iodide bar with little residual gas or $MgCl_2$, this operation generally proceeds smoothly. However, residual magnesium chlo-

*"Some Aspects of the Iodide, or Hot Wire, Process for Manufacture of Zirconium" were described by W. M. Raynor at the ASM Symposium in March.

## Consumable-Electrode Melting of Zr

ride in Kroll-type zirconium occasionally causes excessive splatter onto the tungsten electrode and results in a pick-up of tungsten in the ingot. Since this is generally under 0.10%, it would cause little difficulty in fabrication were it distributed evenly. However, it tends to collect as particles of zirconium-tungsten alloy, and this is highly objectionable when rolling or machining to close tolerances. Also, it has been noted that, in the commercial production of titanium (a very similar metal in many ways) melted by this procedure, the sheet tends to tear at these tungsten inclusions when cross rolled. Undoubtedly it could be difficult to produce zirconium tubing from tungsten-bearing material, since all these difficulties would be accentuated in fabricating operations such as extrusion and drawing.

The scheme which appears to have the greatest promise, and which already has melted more zirconium than any other method, is consumable-electrode arc melting* in a water-cooled copper crucible and inert atmosphere or vacuum. At the present time the Bureau of Mines presses 2x2x20-in. bars of zirconium sponge at 50 tons to the sq.in. and uses them as consumable electrodes. The bars are placed in a helium dry-box on top of the melting furnace proper, and heliarc welded to form a continuous electrode as melting progresses at the lower end. Ingots 6 in. in diameter and weighing about 100 lb. are formed. All melting is performed in a helium-argon atmosphere at about atmospheric pressure. Oxygen pick-up can be held to less than 0.03% and nitrogen 0.001%. If alloys are desired, pills of powder metal are fed periodically, or wire of the desired composition is chopped and dropped into the melt. To obtain better homogeneity and produce sounder ingots, the 6-in. ingots are faced, nippled, and remelted as a consumable electrode into 10-in. ingots weighing up to 500 lb. Distribution of impurities and intentional alloys is comparable to any of the industrial metals. By the use of a retractable base and larger molds, say 16 to 18 in. diameter, ingots weighing up to two tons could be produced without difficulty.

Investigators at Climax Molybdenum Co. have demonstrated that zirconium can be melted in the vacuum arc furnace developed for molybdenum metal by R. M. Parke and J. C. Ham to give satisfactory ingots. This furnace is described in an article by Parke and Ham in *Transactions* of the American Institute of Mining and Metallurgical Engineers for 1947, Vol. 171, p. 416.

**Fabrication of zirconium** follows the same pattern as titanium; the inherent ductility of metal low in oxygen and nitrogen more than offsets the usual difficulties encountered in the working of metals like zinc with hexagonal structure. One of the principal drawbacks to the use of zirconium at elevated temperatures – its abnormal decrease in hot hardness and strength – is partially redeemed by facilitating the fabrication operations. Since the initial curiosity and its accompanying cautious procedures in the handling of a new metal have been outgrown, we have found that zirconium can be handled with conventional machinery and can be forged, rolled, extruded, spun, drawn and

*Described before the ASM Symposium on Zirconium at the Western Metal Congress, March 1953, by W. W. Stephens, H. L. Gilbert and R. A. Beall in a paper entitled "Consumable-Electrode Arc Melting of Zirconium Metal".

*Fig. 6 – Plant for Iodide Refining of Zirconium at Westinghouse Atomic Power Division. Each tank is an oversized vacuum furnace*

*Fig. 7 – When Crystal Bar Has Grown to Maximum Economical Size, the Vacuum Is Broken, the Tank Filled With Water as a Precaution Against Fire, the Bars Hoisted Out and Steam Cleaned, Whereupon They Are Ready for Melting Into Ingots by the Consumable Electrode Process. (Westinghouse Electric Corp.)*

machined without undue difficulty and without any hidden hazards to health.

The early work of Philips Lamp Works in Holland and the Foote Mineral Co. in America was confined to working the "as-deposited" rods without intermediate melting. Sheet, foil, and wire were produced, in pound quantities, by cold working and vacuum annealing. This method has two disadvantages – first, imperfections in crystal boundaries in some of the rods resulted in high trim loss, and second, the small size of the rods prevented fabrication of articles weighing more than a few pounds. In regard to ductility, iodide metal is unquestionably without equal but, as pointed out by Litton, arc or graphite melting of iodide bar into larger masses lessens this advantage and the resulting ingots are similar to Kroll process zirconium in working characteristics.

The economics of hot working of zirconium represents a balance between ease of working, as the temperature is increased, and the resulting loss of metal by oxidation. The practical limit is 1600° F. for heavy sections and 1200 for thin. Recrystallization temperature is about 1100° F. and the metal has plasticity necessary for working at this temperature, but the 1200 to 1600° F. interval represents a good working range for the mill. In early work on Kroll process zirconium by the Bureau of Mines in the U. S. and by Murex, Ltd., in England, it was protected by steel sheaths which were stripped before the finishing operations. This was purely an expedient to conserve expensive metal and was limited to ingots up to 25 lb. Since the ingot size has now increased to over 500 lb. and will eventually rise to 1000 lb. or more, the surface-volume relationships are more favorable for decreased metal loss; the cost of the metal has also decreased. Except in certain special instances, zirconium is now worked in air without special protection.

Ingots have been forged at 1600 to 1200° F. to shape into slabs, prior to rolling billets or finished shapes. The rate of forging is not critical (as it is for magnesium), and zirconium can be worked equally well by steam or air hammers, or it can be press-forged in hydraulic machines. As is generally true, the initial working must be done with light blows until the cast structure is broken up.

Rolling is best performed hot in all sections down to 0.040 to 0.050 in. Roll loads are less than those needed for stainless steel and higher than those for 70-30 brasses. In thinner sections the oxidation of zirconium becomes more significant; thin sheet must be made by alternately cold rolling and annealing. G. L. Miller ("Commercial Uses of Zirconium Developing", *Iron Age*, Vol. 167, May 17, 1951, p. 83) and older publications of the Philips group in the Netherlands say that a satisfactory anneal for further cold working can be achieved by heating in air at 1200° F. for 10 to 30 sec. While this does not harm the metal seriously and the attendant cleaning of the oxidized surface is less expensive than a vacuum anneal, such a practice must be used with caution. (See "Annealing of Titanium and Zirconium", by A. M. Bounds and H. W. Cooper, *Metal*

*Progress*, January 1951, p. 69.)

Cold reductions of 40 to 50% can be made safely on arc-melted material from 0.5 to 0.05 in. in thickness. Zirconium work hardens rapidly during the first 10 to 20% reduction and then at a much lower rate. While this is no drawback in flat rolling, it does require more frequent annealing in bending, drawing, and spinning.

Zirconium can be extruded into rod and tubing, as described by A. M. Bounds and H. W. Cooper in *Metal Progress* for August 1950 (p. 185). Here, another perverse feature makes its appearance, as it does also in deep drawing and wiredrawing. Zirconium, like titanium and tantalum, has a strong tendency to seize the die wall. Copper canning or plating, colloidal graphite, and other pressure lubricants have been used to overcome this seizing. However, there appear to be no unsolvable problems in extruding seamless tubing and drawing or swaging to produce small sizes. Tubing can also be made by heliarc welding of zirconium skelp and drawing to size.

*Fig. 8 – Appearance of Pressed Bar and of Rough and Finished Zirconium Ingots*

### MECHANICAL AND PHYSICAL PROPERTIES

Zirconium can be spun, cupped, and drawn, but, as yet, little specific data have been published to guide the shopman. Temperatures from 700 to 1100° F. are usually satisfactory and the oxide is one of the best lubricants known. In spite of its hexagonal structure, zirconium presents few problems that can be traced to directional properties.

Metallurgists may have been confused by the discordance in the published properties of zirconium as prepared by different reduction methods. (Sintered compacts have also been tested.) Discrepancies in the data are principally due to the failure to report oxygen and nitrogen analyses of the metal. Its hardness and strength increase with oxygen content and

**Table I – Mechanical Properties of Commercial Zirconium**

| | Kroll Process* | | Iodide Process† | |
|---|---|---|---|---|
| | 50% Cold Worked | Annealed 1300° F. | Hard Drawn | Annealed 1450° F. |
| Ultimate tensile strength | 82,600 psi. | 49,000 psi. | 83,300 psi. | 35,900 psi. |
| Proof stress, 0.2% offset | 75,400 | 29,200 | 69,700 | 15,900 |
| Proportional limit, 0.01 offset | 41,800 | 16,900 | 32,100 | 8,350 |
| Elongation % | – | – | 18% | 31% |
| Modulus of elasticity | 12,800,000 | 13,700,000 | 14,500,000 | 11,350,000 |
| Hardness | B-95 | B-83 | B-87.4 | B-30.0 |
| Charpy impact resistance | 14.8 ft-lb. | – | 1.5 to 3.5 ft-lb. | 2.5 to 6.0 ft-lb. |

*Oxygen 0.11%, nitrogen 0.01%  †Oxygen 0.04 to 0.06%

this fact is reflected in the strength of zirconium produced by different methods. Iodide zirconium has the lowest strength, calcium-reduced zirconium the highest, and Kroll process zirconium shows intermediate values.

Kroll process material containing 0.11% oxygen and 0.01% nitrogen, which has been arc melted and rolled to $\frac{1}{16}$-in. sheet, has properties shown in Table I.

Data on iodide material which probably contained 0.04 to 0.06% oxygen are also given in Table I.

Variations in values for modulus of elasticity between the annealed and hard drawn metal probably are attributable to difficulties in obtaining precise values, rather than being a unique characteristic of the metal. Scattered values of Charpy impact strength have not been fully explained. Random values above 50 ft-lb. have been reported. Zirconium, like most nonferrous metals, does not show brittle fractures at low temperature. W. L. Mudge, Jr., reported some studies on the "Effect of Hydrogen on the Embrittlement of Zirconium and Zirconium-Tin Alloys" to the ASM Symposium (Los Angeles, March 1953). He concluded that hydrogen in amounts greater than 10 ppm. was responsible for the fact that metal held above 600° F. and slowly cooled would show unduly low V-notch Charpy impact values when tested at temperatures between 32 and 400° F.

The effect of oxygen in hydrogen-free zirconium has been studied by R. M. Treco of Bridgeport Brass Co. (See "Some Properties of High-Purity Zirconium and Dilute Alloys With Oxygen", presented to the ASM Symposium.) Treco rolled iodide zirconium to 0.170-in. strips by stages of cold rolling and annealing, and cut test pieces 3 in. long by ¼ in. wide. These were degassed in high vacuum and then oxygen in various amounts added by the well-known "gettering" activity of zirconium. Table II summarizes his results.

**Table II – Influence of Oxygen on Hydrogen-Free Zirconium**
From Results by R. M. Treco

| Atoms % Oxygen | Ultimate Strength | 0.2 % Yield | Elongation % in 1 In. | Hardness A-Scale | Electrical Resistivity* |
|---|---|---|---|---|---|
| Nil | 29,000 | 7,000 | 32 | 20 | 39 |
| 0.5 | 39,000 | 26,000 | 16 | 36 | 42.5 |
| 1.0 | 50,000 | 34,000 | 7 | 46 | 46.5 |
| 1.5 | 59,000 | 42,000 | 5 | 52 | 50 |
| 2.0 | 70,000 | 49,000 | 4 | 57 | 54 |
| 2.5 | 81,000 | 56,000 | 3 | 60 | 57.5 |

*In ohm-cm. × $10^6$

**Physical Properties** – A comprehensive compilation of these data in the unclassified literature up to 1949 has been prepared by F. W. Boulger for the Atomic Energy Commission. The document is called "The Properties of Zirconium", numbered AECD-2726; copies may be secured for 30¢ from the Technical Information Division, Oak Ridge Operations, Oak Ridge, Tenn.

Zirconium solidifies in the body-centered cubic system at 3325° F. (1830° C.) and undergoes an allotropic transformation to the hexagonal close-packed structure at 1585° F. (863° C.), which is the stable form at room temperature. Both the physical and the mechanical properties of zirconium are profoundly influenced by minute amounts of gaseous impurities. Most of the data in Table III are for high-purity iodide type of zirconium.

**Table III – Physical Properties of Zirconium**

| | | |
|---|---|---|
| Thermal properties | | |
| Melting point | | 1830 ± 40° C. |
| Allotropic transformation temperature | | 863 ± 3° C. |
| Specific heat, zero to 100° C. | | 0.068 cal. per g. |
| Coefficient of thermal expansion, 20 to 200° C. | | 5.4 × $10^{-6}$ per °C. |
| Electrical properties | | |
| (1) Resistivity: iodide bar | | 39 × $10^{-6}$ ohm-cm. |
| Kroll bar | | 48 × $10^{-6}$ ohm-cm. |
| (2) Temperature coefficient of resistivity: iodide bar | | 0.0044 per °C. |
| Lattice constants | Hexagonal Close Packed | Body-Centered Cubic |
| a | 3.228 A | 3.61 A |
| c | 5.120 A | — |
| c/a | 1.59 | — |
| Interatomic distances | | |
| $d_1$ | 3.16 A | 3.12 A |
| $d_2$ | 3.22 A | — |

## CORROSION OF ZIRCONIUM

One outstanding characteristic of zirconium accounting for its important commercial interest is its resistance to corrosion; in various mediums it surpasses stainless steel and resembles tantalum.

Its resistance to attack by alkalis is excellent. It is completely resistant to hydroxide solutions in all concentrations up to their boiling points; even fused caustic has no effect.

In acid solutions, the corrosion resistance is not so sharply defined. Zir-

conium shows excellent corrosion resistance at all temperatures in $H_2SO_4$ solutions up to 80% concentration by weight. Above this point, there is a sharp increase in the rate of corrosion.

Its corrosion by nitric acid solutions is negligible for all concentrations and for temperatures to 100° C. Aqua regia attacks zirconium. While $HNO_3$ in any concentration does not attack zirconium, the addition of a small amount of sulphuric acid destroys the corrosion resistance.

Hydrochloric acid in concentrations from 0 to 20% by weight and at temperatures up to 100° C. does not attack zirconium. It is also fully resistant to all concentrations of phosphoric acid up to 60° C., and up to 60% concentration by weight at 100° C.

Zirconium fully resists attack by metal chloride solutions with the exception of ferric and cupric chloride. In these two it suffers an embrittlement type of attack which, in the most severe form, completely disintegrates the metal into a fine powder.

Other solutions in which zirconium is not corrosion resistant are water saturated with chlorine, and red fuming nitric acid. In white fuming nitric acid, the corrosion resistance is only good.*

The resistance to corrosion by acids and bases makes zirconium a good substitute for tantalum in orthopedic surgery. No known compound of zirconium has a toxic effect on the body. Bone and tissues will adhere to this metal. Its mechanical strength, wear resistance and low density make it a very useful metal for special surgical applications.

The resistance of zirconium to corrosion by various hot gases is generally very poor, since the metal is high in the chemical activity table. The protective oxide film which accounts for the corrosion resistance toward most solutions, is absent at higher temperatures, since the oxide is rapidly dissolved by the base metal at 1500° F. and an active surface is continually exposed. Pieces of zirconium may safely be heated in air to 1375° F. for hot working, and the resulting surface oxides can be removed by sand-blasting and pickling in hydrofluoric acid. Thin sections must be protected from contact with air by either heating in a vacuum or in an inert atmosphere of helium or argon.

*This topic was discussed at some length at the Symposium by Lex B. Golden in a paper entitled "The Corrosion Resistance of Zirconium and Its Alloys".

Zirconium has an affinity for nearly all gases. Hydrogen is readily absorbed above 925° F. and nitrogen is rapidly absorbed above 1650° F. Zirconium reacts with $CO_2$, CO and $SO_2$ at elevated temperatures, liberating elemental carbon or sulphur. Pure $SO_2$ gas has little effect on zirconium at 925° F. (500° C.) but reacts with it to form a voluminous oxide at 1110° F. (600° C.).

Hydrogen absorption is a reversible. Zirconium combines with hydrogen in increasing amounts up to the allotropic temperature, but there much of the hydrogen is rejected. Upon cooling, hydrogen is reabsorbed. This has been used as a method for purifying hydrogen, since oxygen and water vapor contained in the gas are retained by hot zirconium.

### MACHINING OF ZIRCONIUM

Pure, ductile zirconium presents little difficulty to a machinist provided he uses sharp tool bits. Machining is similar to pure copper or stainless steel. Although zirconium is best machined when using a coolant, most of the cutting done at the Bureau of Mines is dry because the turnings are used for remelt stock. Under dry conditions, a good lathe job can be done at a speed of 100 ft. per min., cutting to a depth of $\frac{1}{8}$ in. and a feed of $\frac{1}{32}$ in. per revolution. This speed can be greatly increased by cooling the tool and work with a liquid or a blast of cold air.

Zirconium cuts freely but is tough and abrasive to the tools. Dull tool bits also work harden the metal rapidly. Because of this, tungsten carbide tool bits are recommended, although a high grade toolsteel will suffice. Satisfactory tool clearances are a 10° front clearance, 7° side clearance, back rake of 0 to 10° (Carboloy or toolsteel bit) and side rake of 0 to 10°.

Zirconium can be and is shaped by all other tooling operations such as boring, drilling, planing, milling and shaping. In all such work it is important to keep the tools sharp. A low operating speed is generally more efficient than a high speed because the metal is comparatively soft but tough. This is especially true in drilling and grinding.

The metal may be satisfactorily parted by a coarse, loosely bonded cut-off wheel such as Carborundum 75C46-Q9-BM31 or Allison Type 120C $1\frac{1}{2}$. A fine-grained and strongly bonded wheel will not cut efficiently and the work will tend to overheat. Regardless of the abrasive used, it will be rapidly consumed, because

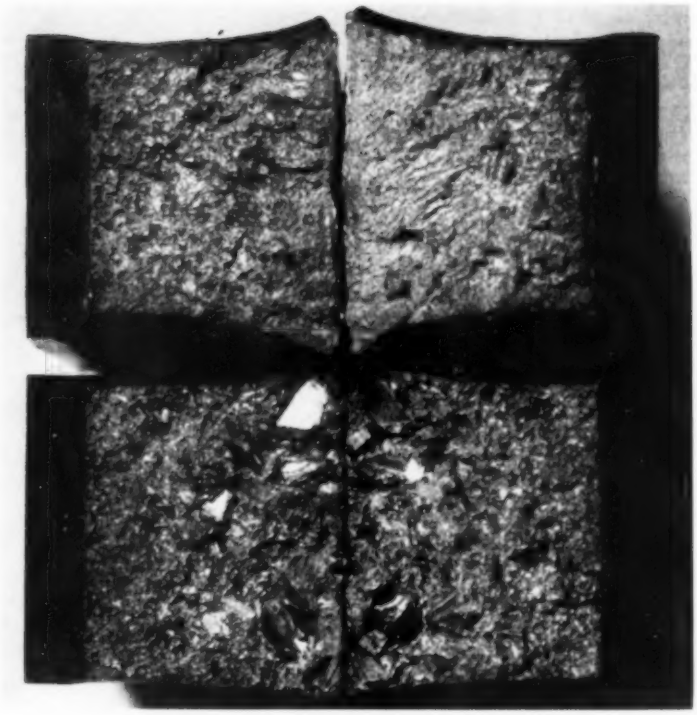


*Fig. 9 – Fracture Surfaces of Zirconium Alloyed With 2.5% Tin. Ductile specimen at top, brittle below*

zirconium readily adheres to (and fouls up) a grinding wheel in a manner comparable to aluminum and brass.

### ALLOYS OF ZIRCONIUM

Few metals in history have been investigated so intensively and extensively in the past five years as zirconium and its alloys. The article by A. D. Schwope on p. 75 of this issue gives an idea of how the interesting alloys were predicted. Work on at least 12 alloy systems covering the zirconium-rich portions of the diagram has been completed and is or will be published. These systems include nickel, manganese, tin, silicon, iron, chromium, titanium, copper, molybdenum, tungsten, and aluminum; the first four of these were presented at the Zirconium Symposium at the Western Metal Congress in Los Angeles last March. Although few mechanical properties have been reported, it seems that no vast improvements, such as those found in titanium alloy metallurgy, will be forthcoming.

The Armour Research Foundation of Illinois Institute of Technology, Chicago, and the Bureau of Mines have been responsible for most of the American work on binary diagrams. (The work at Armour has been summarized in "Phase Diagrams of Zirconium-Base Binary Alloys", published by the Foundation in April 1952.)

Most of the zirconium alloy systems studied to date show limited solubility of the alloying element in beta zirconium and negligible solubility in the low-temperature alpha phase. The beta solution decomposes eutectoidally on cooling to give alpha zirconium and an intermediate phase. The salient features of seven of these systems are given in Table IV on the next page.

The approximate eutectoid compositions and temperatures of five titanium alloy systems are presented in Table V for comparison purposes.

Solubility of the alloying elements of Table IV in titanium is three to eight times their solubility in zirconium. Whereas beta titanium, or mixed beta-plus-alpha structures, can be retained in all these titanium systems, there are practically no reports of retained beta in similar zirconium alloy systems.

This lower solubility is the basis for belief that workable zirconium alloys having ultimate tensile strengths over 100,000 psi. will not be common. An exception may come in the tantalum system where the beta solubility is much higher; tensile strengths of 150,000 psi. have been reported by F. B. Litton in *Iron Age*, Vol. 167, April 5, 1951, p. 95.

Aluminum and tin show appreciable solubility in alpha zirconium – about 3½% and 9% respectively. Apparently this limit could not be approached in commercial Zn-Al alloys due to difficulty in fabricating common shapes. Moderate percentages of tin, while not imparting phenomenal tensile strength, will markedly raise the yield strength without excessive loss in ductility.

Zirconium-titanium alloys are unique in that they form completely isomorphous solutions of both alpha and beta forms with the transformation point depressed to about 1000° F. (535°

**Table IV – Zirconium Alloy Systems of the Fe-$Fe_3C$ Type**

| System | Maximum Solubility | | Temperatures | | Composition | | First Intermediate Phase |
|---|---|---|---|---|---|---|---|
| | In Alpha | In Beta | Eutectoid | Eutectic | Eutectoid | Eutectic | |
| Zr-Fe | – | 5.5 | 800° C. | 934° C. | 2.5 | 16 | $ZrFe_2$ |
| Zr-Ni | – | 1.9 | 808 | 961 | 1.3 | 17 | $Zr_2Ni$ |
| Zr-Mn | – | 6.5 | 795 | 1150 | 3.0 | 22.5 | $Zr_2Mn_3$ |
| Zr-Cr | 0.1 | 6 to 8 | 805 | 1380 | 1.7 | 18 | $ZrCr_2$ |
| Zr-Mo | 0.18 | 22 | 780 | 1520 | 7.5 | 31 | $ZrMoO_2$ |
| Zr-W | – | 8 | 850 | 1650 | 0.5 | 18 | $ZrW_2$ |
| Zr-Cu | 0.2 | 3.8 | 822 | 995 | 1.6 | 21 | $Zr_2Cu$ |

C.) at 50 atomic %. Graphite melted alloys of this composition have a tensile strength above 150,000 psi. with a rather low elongation.

## USES

Zirconium is a product of the Atomic Age. [This is clearly expounded by E. C. Miller in the leading article in this issue of *Metal Progress.*] The demands of the Atomic Energy Commission for high-purity metals and alloys, odd fabricated shapes and close tolerances have manifested themselves in many ways in the past ten years and have called upon the metallurgist to meet unconventional standards, chief of which is termed "neutron economy". This term must always remain a relative one since it has to do with the relative proportion of the fissionable material which can be utilized in a chain reaction, and the value of a gram of this plutonium or $U^{235}$ cannot be computed. Their use for power development, however, demands the best possible combination of structural materials to produce recoverable heat with a minimum of waste.

Published figures for neutron absorption exclude all but four metals – beryllium, magnesium, aluminum, and zirconium – from the high-flux zone in thermal reactors. Beryllium is by far the best of the four in regard to neutron economy; however, it is difficult to fabricate in other than simple shapes. Even if it could be worked easily, nature has placed a strict limitation on man's use of beryllium by scattering it so widely that there simply is not enough to satisfy the demands. Magnesium, while inexhaustible in supply, is ruled out because of its poor heat resistance at nominal temperatures. Aluminum is still used in the plutonium piles at Hanford, Wash., but "the reason the Hanford reactors were not designed to produce power is not one of nuclear physics . . . . However, if the temperature is raised substantially, one immediately runs into corrosion problems. No engineer in his right mind would design a steam boiler to be built of pure aluminum, yet the water tubes in a Hanford reactor are made of aluminum – because the requirement of low neutron absorption rules out all iron and copper alloys."*

**Table V – Data on Five Titanium Systems**

| System | Eutectoid Composition | Eutectoid Temperature |
|---|---|---|
| Ti-Fe | 12 wt. % | 580° C. |
| Ti-Ni | 8 | 780 |
| Ti-Mn | 20 | 550 |
| Ti-Cr | 14 | 670 |
| Ti-Cu | 9 | 780 |

Zirconium then becomes the outstanding metal with low neutron absorption for high-temperature application in the development of reactors. Its thermal conductivity is only fair but its strength up to 1000° F. and excellent corrosion resistance make it the most attractive metal available for general use. A word of caution should be mentioned at this point. Zirconium is not the ideal construction material for *all* nuclear reactors. Some reactors use neutrons at high speed. As the neutrons increase in speed they behave more like X-rays, and under such conditions zirconium possesses no advantages – in fact, it would have a higher absorption coefficient than ordinary steels.

The uses of zirconium for chain reactors, while all-important at the present time, overshadow many other interesting possibilities for the industrial use of this metal or its alloys. One important potential use appears to be in the heavy chemical industry, where its excellent corrosion resistance to a wide variety of acids, especially hydrochloric, and to strong bases makes it particularly promising. To date, the press of defense work has left little time for such normal developments.

*Quotation from K. S. Pitzer and S. G. English, "Role of Chemistry in the Development of Atomic Energy", *Chemical and Engineering News*, Nov. 12, 1951, p. 4836.

# Book Review

## Foundry Bronzes

*Cast Bronze, by Harold J. Roast. Cleveland. American Society for Metals. 460 pages, 87 illustrations, 41 tables, $4.*

BY H. M. ST. JOHN*

An unusual book, quite unlike any previous work on foundry practice. It contains something of interest to almost any reader with a technical background. The chapter entitled "The Historical Viewpoint" traces, step by step, the history of bronze casting from prehistoric man, who had no bronze castings, down to the most modern methods of making and testing bronze. The chapter on "Honesty in the Foundry Business" is a noteworthy philosophical essay. Then there is a chapter on how to teach nonferrous foundry metallurgy, with enough detail to relieve the instructor of practically all of his planning chores – even the type of notebook to be used by the student is specified. All this in addition to a wealth of information for those who make castings, who design castings, who specify castings, who buy castings, who use castings.

When one attempts to discover how it is possible to pack so much of interest and value into less than 500 pages, two things become apparent. It is never necessary to read a sentence twice to discern the author's meaning. There are no unnecessary words. The result is a simplicity and clarity decidedly unusual in technical writing.

The author states frankly that he has depended almost wholly on his own experience. (Let us say at once that this has been long, comprehensive and diversified.) Exceptions are the chapters on beryllium bronze, architectural bronze and the nickel bronzes, which have been ably treated by specialists in those fields. Six other classes of bronzes, including the tin bronzes, the author takes over as well covered by his own experience. Because there have been many developments since bronze was originally defined as an alloy of copper and tin, we like Mr. Roast's definition of bronze as any copper alloy in which the dominant alloying element is something other than zinc. Of course, even this fails to explain "manganese bronze".

Each species of bronze has its own chapter which deals not only with foundry practice but also with the engineering properties of the alloys and their behavior in the machine shop and, finally, how well-made parts act in the hands of the user. Effects of impurities are also considered. However, it is surprising that one of the most useful tin bronzes, commonly known in the United States as Navy M (88 Cu, 6 Sn, 1.5 Pb, 4.5 Zn), is practically ignored. Many foundrymen will also question the 1900° F. pouring temperature listed as best for the tin bronzes and others having a similar melting point. In actual practice with small castings, pouring must commonly be started at temperatures from 2100° F. – and even as high as 2300° F. Of course, the design of the casting and the number of molds to be poured from one pot of metal have a large bearing on this.

*Harold J. Roast*

Thorough as has been the author's experience it does not suffer one limitation; it has obviously been largely confined to jobbing foundry work. The production foundryman, who is called upon to make many thousands of identical castings, year in and year out, maintaining top quality at the lowest possible cost, will have to take exception to some of the recommendations which Mr. Roast considers highly important. These exceptions will be taken with some sadness, accompanied by

*H. M. St. John is nonferrous foundry superintendent for Crane Co., Chicago.

the inner thought: "Oh, if I could only do what the man says and still get production."

For example, it would be nice to blast all the molding sand from gates and sprues before remelting but it isn't essential and it does cost something. Also, it may be troublesome to change from one alloy to another in hearth-type furnaces – but it has to be done, and without contaminating the subsequent metal. Further, to let a pot of metal stand on the floor for two minutes or more while it cools and degasses itself may be ideal but there just isn't time for that. One adds a couple of gates, gives the metal a stir, checks the temperature once more and proceeds to pour. Such differences of viewpoint may tempt a production foundryman to give the book far less credit than it deserves.

Any foundryman will profit by reading the chapter entitled "Inner Life and Activity of Metals", which gives a simple picture of basic metallurgy. The chapter on chemical and physical testing, particularly that portion which deals with test bars and their function, should be required reading. If the foundryman also reads the chapter on the engineering viewpoint he will gain new insight as to the peculiarities of casting design and specifications. This chapter will benefit the designing engineer and the user to an even greater extent.

Throughout the book the author has used trade names of the equipment and materials which he has found best suited to his purpose and has often given names and addresses of manufacturers. That this information will be useful to many readers can hardly be denied, but surely manufacturers whose products are not mentioned are likely to say, "Why does my competitor rate and not me?" In his preface Mr. Roast says: "No apology is considered necessary for the use of trade names. Where the manufacturers of material and equipment are mentioned, it should be understood that the author does so because these are the particular items with which he is familiar. On the other hand, there are doubtless other suppliers of equal merit to those cited." Whether this statement will pacify the unmentioned manufacturers remains to be seen. However, one must recognize that this identification of recommended products is quite in keeping with the forthright manner in which the author expresses all of his opinions.

Mr. Roast's goal has been to write a book which would give the nonferrous foundryman something he has never had – a complete and authoritative treatise covering every detail of his work. If the author has failed in some particulars to reach this goal, he has at least come close to it and has at the same time produced a work of substantial literary merit.

We like the book.

---

# New Corrosion Problems Created by High Temperatures and

FOR A SUBJECT which involves such countless ramifications as found in corrosion prevention, the National Association of Corrosion Engineers achieved a well-balanced program in its Ninth Annual Conference held recently in Chicago. The 43 papers presented at this meeting were divided among nine symposiums devoted to scientific principles, fresh and salt water corrosion, oxidation and corrosion at elevated temperatures, protective coatings, cathodic protection, and to corrosion problems in the power and communication, oil and gas production, and chemical industries. In addition, a number of subjects pertaining to pipeline coatings were covered in a round-table discussion. Especially timely were the reports of investigations of the corrosion problems associated with the high temperatures being

# Chemical Processes

used by various industries. A brief résumé of some of the papers follows:

**Elevated Temperatures** – F. C. Monkman of Massachusetts Institute of Technology has investigated the accelerated oxidation of Types 316, 321 and 347 stainless in the presence of vanadium oxide. The studies, conducted in association with N. J. Grant, also of the M.I.T. metallurgical faculty, provided data on accelerated oxidation due to vanadium carried in the crude fuel oils used in the firing of heating furnaces, power boilers, and gas turbines. Chemical analysis and X-ray diffraction photographs proved that a vanadium-rich liquid oxide forms as a thin film on the surface of the stainless steel, and that severity of oxidation is proportional to the liquid vanadium-rich oxide concentration at the interface between metal and metal oxide.

The influence of $V_2O_5$ was also referred to by H. F. Peters of Lukens Steel Co. in his report of high-temperature lead corrosion of wrought steel kettles used for lead baths. The presence of 0.1% of $V_2O_5$ in the bath, used in the temperature range of 1000 to 1200° F., caused failure after 60 hr. Tests at 1200° F. of stressed samples of silicon-killed and of rimmed steels are being made to learn whether there is any difference in their behavior for this kind of service.

A lead bath that was relatively high in lead oxide caused earlier stress-rupture failure of steel specimens than did a similar bath under an argon atmosphere, this difference being, for specimens stressed to 12,000 psi., 60 hr. to failure for the former and 173 hr. for the latter. A comparison of the effect of stressing on the samples tested in the bath containing high lead oxide showed that specimens with a stress of 15,000 psi. failed at the end of 5 hr., 12,000 psi. (as already mentioned) at 60 hr., 8000 psi. at 173 hr., and the samples carrying only 2000-psi. stress did not fail after one month.

In discussion, E. N. Skinner of International Nickel Co. remarked that the steel used in jet-engine exhaust assemblies was subject to excessive intergranular attack by the lead in exhaust gases from high octane gasoline if the steel contained silicon.

In another investigation, E. D. Weisert and W. O. Binder found that boron used as a strengthening agent in chromium-nickel-cobalt-iron alloys impairs their oxidation resistance at temperatures above 1700° F. The tests were conducted in air at 1650, 1830 and 2012° F., these temperatures being higher than those used in gas turbine applications, since the adverse effect of boron is difficult to detect at 1650° F. or lower. The data obtained for this particular group of cast alloys reveal that iron and boron do the most harm, as far as oxidation resistance is concerned. A deleterious effect of cobalt was also noted – contrary to general experience with this highly important constituent in high-temperature alloys – and the authors suggest that the conclusions apply only to the complex alloys studied, namely, castings containing 60% Co and 0.70% B, when compared with others containing 40% Co and 0.62% B. (Nickel was substituted for some of the cobalt in the second of these experimental compositions.) Molybdenum also lowered the oxidation resistance of these cast alloys.

X-ray diffraction studies of the oxide scales showed that while boron does not appear to exert a direct influence on their constitution, it does accelerate the formation of known undesirable constituents – complex spinels and tungstates, the early formation of which appears to be very detrimental to subsequent resistance to

**Reported by JOHN PARINA, JR.**
**Associate Editor of Metal Progress**

scaling. Mr. Weisert stated that alloys for this kind of application can employ boron and still have good resistance to corrosion if the iron content is held below 6%, if tungsten is used as a strengthening agent in place of molybdenum, and if excessive cobalt content is avoided, largely through replacement of some of the cobalt by nickel.

Very little has been published on the corrosion resistance of metals and alloys to chemical solutions which are heated to temperatures above their boiling points at atmospheric pressure – or even to superheated distilled water under conditions which transcend those met in modern steam power plants. In view of the shortage of this knowledge at a time when higher temperatures and pressures are being used by the chemical processing industries, there is urgent need for work such as that reported in the investigation made by F. H. Beck and M. G. Fontana of Ohio State University.

Data were presented by Dr. Beck on the corrosiveness of nitric, phosphoric and acetic acids and sodium hydroxide at temperatures up to 425° F. The solutions were in contact with cast stainless alloys, CB-30 (20% Cr + Ni), CF-8 (20 Cr, 10 Ni, low C), CF-8M (20 Cr, 10 Ni, low C, plus Mo), CN-7MCu (20 Cr, 29 Ni, plus Cu and Mo), and titanium. In some instances attack of unexpected severity occurred; on the other hand, certain metallic ions had equally surprising effects, inhibiting corrosive action. For example, copper ions decrease corrosion of stainless steel by phosphoric acid. However, the presence of copper and molybdenum in the CN-7MCu alloy *improves* its resistance to 85% phosphoric acid at 275° F. Oxygen introduced into hot 65% nitric acid at pressures up to 500 psi. reduced the corrosion of CF-8 alloy. Subsurface corrosion of this alloy by hot sodium hydroxide of 40 to 60% concentration was found to be very severe, yet it left a surface film of metal. Cast titanium showed good corrosion resistance to all concentrations of nitric acid.

### REFINERY PROCESSES

The effect of hydrogen sulphide solutions on steels used in catalytic crackers was reported in the paper by T. Skei, A. Wachter, W. A. Bonner and H. O. Barnham of Shell Development Co. Damage occurred as hydrogen blisters, fissures and embrittlement.

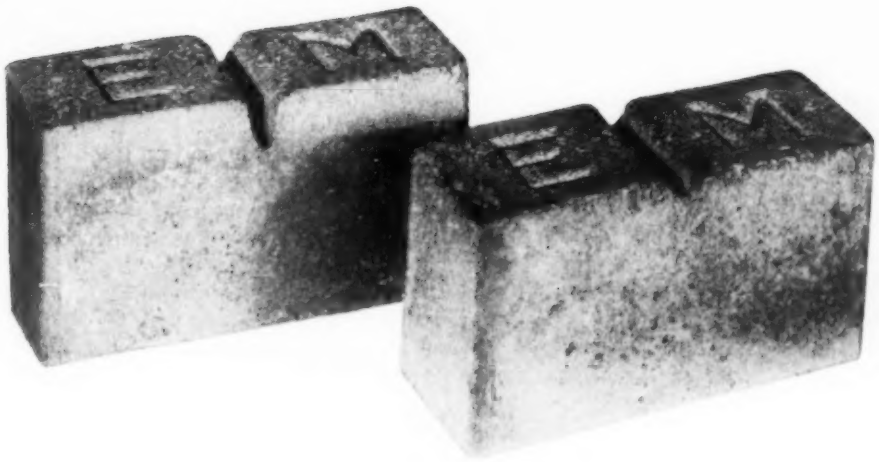
Influence of environmental factors on the rate of hydrogen penetration in carbon steel was studied by measuring the volume of gas which passed through a thin sheet. Penetration was stopped after a short time in some hydrogen sulphide environments, whereas it continued in alkaline solutions having cyanide ions. Corrosion occurred with the latter condition. The results are attributed, respectively, to the formation of a protective scale of iron sulphide and to the prevention of its development by the presence of the ferrocyanide complex. Prevention of corrosion and accompanying damage from hydrogen in alkaline cyanide-sulphide solution was obtained by destruction of cyanide ion by reaction with polysulphide ion to form thiocyanate ion.

The corrosion caused by hydrogen sulphide was also referred to by E. H. Tandy in his discussion of the need for constant inspection of refinery equipment. He observed that sulphur compounds break down during distillation and form hydrogen sulphide. Another cause of corrosion is the naphthenic acids which may be present in the crude or may form during refining. These are most corrosive at their condensation temperatures, causing severe localized attack of surfaces on which they condense.

### PASSIVE STATE OF TITANIUM

In his report on the behavior of titanium in sulphuric and hydrochloric acids, W. W. Harple of Allegheny Ludlum Steel Corp. stated that its corrosion resistance in a particular medium depends on its ability to maintain its passivity, titanium being very similar to stainless steels in this respect. Samples of titanium were tested in sulphuric acid of 0 to 95% concentration and in hydrochloric acid of 0 to 37% concentration at temperatures of 100, 150, 175 and 200° F.

It was found that the passive state of titanium changes to the active state in sulphuric acid of 0.5% concentration at 100° F., and in hydrochloric acid of 3.5% concentration at 100° F. The effect of various inorganic salts and oxidizing agents on the passive-active boundary was also studied; of these $CuSO_4$ and $NiSO_4$ were the most beneficial in sulphuric acid at 100° F., decreasing the corrosion rate to practically zero. Since it is unusual to obtain a high degree of inhibition in hydrochloric acid solutions, it was especially significant that the addition of compounds such as $CrO_3$ and $CuSO_4$ could improve the behavior of titanium under these conditions.

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# Correspondence

## Notable Metals Engineers

NEW YORK CITY

A brief analysis of metallurgical achievement is offered as a stimulus to forward-looking men among the 22,500 belonging to the American Society for Metals.

It is also offered as an item for a "Society for the History of Metals". In this neglected field, nuclei of publications, artifacts and amateurs already exist. We amateurs should get together. A propitious time would be the Metals Congress in Cleveland next October. We might well meet in the Sauveur Room of ASM Headquarters.

The presidency of the Society is one of the high awards that the profession holds out for metals engineers. The 35th will take office next October. Two other awards which this analysis takes into account are the Sauveur Achievement Medal and the Campbell Memorial Lectureship. In addition, there is the general recognition by scientists as reflected in the biographical dictionary of "American Men of Science" and the general recognition by the larger community as reflected by "Who's Who in America".

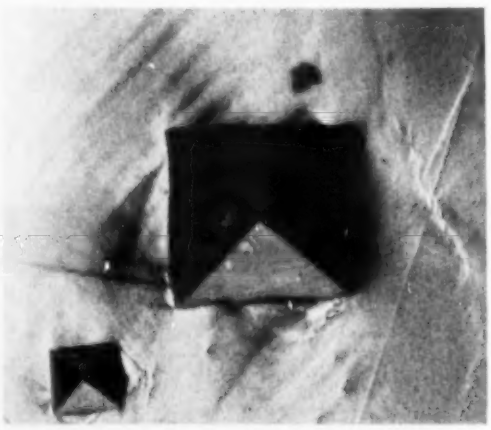
Data of only 19 of the 35 ASM presidents have been studied, simply because these two directories listed them, but a sampling of the data available elsewhere indicated that the tabulation so derived adequately reflects what a summary of all 35 would show. Scholarship would like to take into account the careers of all ASM Presidents, Sauveur Achievement Medalists, Campbell Memorial Lecturers, plus the parallel facts of all the other ASM notables – the Honorary Members, Howe Medalists, Gold Medalists, Medalists for the Advancement of Research. But that must wait.

Meanwhile let the following be a stimulus to metallurgical accomplishments and honors:

| | |
|---|---|
| Presidents, ASM | 35 |
| Age at office, average (Youngest 37; oldest 69) | 50.4 yr. |
| Directoried | 19 or 55% |
| In industry | 12 63% |
| In education | 7 37% |
| University-trained | 17 90% |
| Age at first degree, average (Youngest 18; oldest 27) | 22 yr. |
| Age (for 12) at advanced degree, average (Youngest 22; oldest 40) | 27.3 yr. |
| Sauveur Medalists | 17 |
| Medalists who have also been presidents | 8 or 40% |
| Directoried medalists-presidents | 5 |
| Age at honor, average (Youngest 47; oldest 55) | 51 |
| Campbell Lecturers | 27 |
| Lecturers who have also been presidents | 9 or 33% |
| Directoried lecturers-presidents | 9 |
| Age at honor, average (Youngest 35; oldest 46) | 41 yr. |

MYRON WEISS

*Fig. 1 – Diamond Pyramid Indentation in Mechanically Polished Titanium. Load 3 kg., 200 ×*



## No Trouble With Titanium Sticking to Indenter

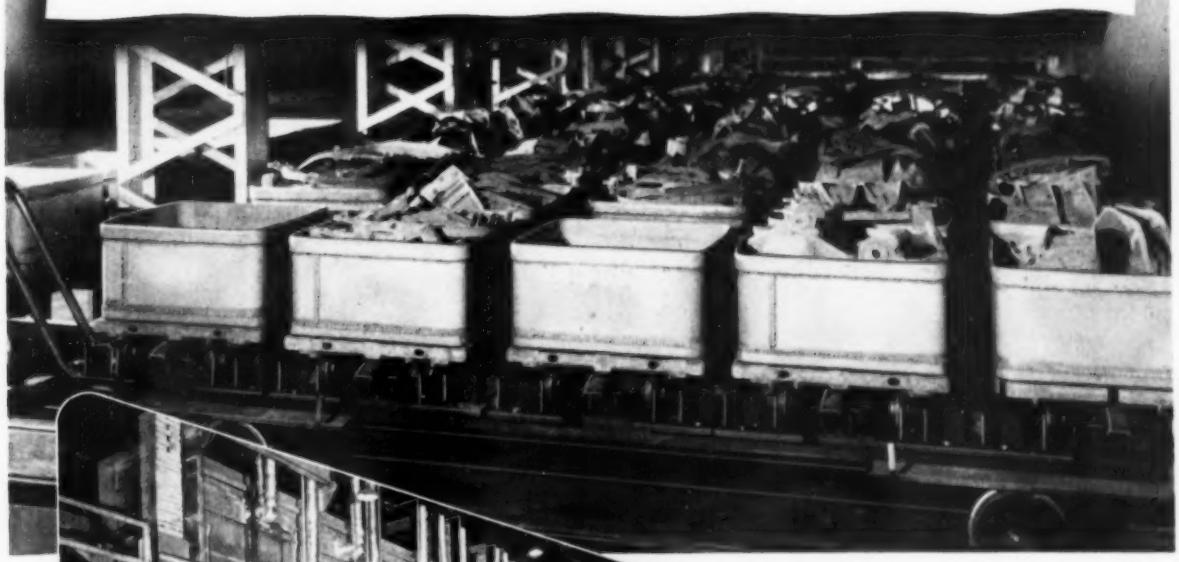
LONDON

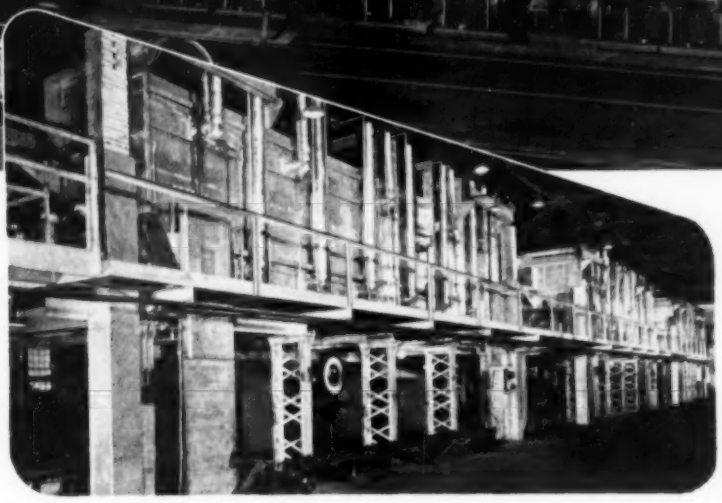
With the note by H. P. Leighly, Jr., and H. L. Walker on observations made from hardness tests of titanium metal with a diamond indenter, there appeared a photograph to show the degree of metal adherence to the diamond pyramid (see *Metal Progress*, November 1952, p. 109). As neither the magnification nor the load which was applied in the particular test was indicated, no information on the extent of the damage impression could be gained. In addition it would have been an advantage if the actual indentation would have been shown so that the impossibility of measuring would have become obvious.

Subsequent to the publication of the aforementioned note, an electropolished sample

*(Continued on p. 118)*

# PSC *"Light Weight"* ANNEALING BOXES CUT HANDLING AND HEATING TIME





*Left, a battery of 3 HOLCROFT overhead malleablizing furnaces at a large midwest foundry. Above, PSC boxes on the floor level, ready for elevating into a furnace.*

Designed for use with conveyor-fed furnaces, the above PSC "Light-Weight" annealing boxes handle rapidly and easily through any load, unload, transfer or switch movement possible on a 90° conveyor.

Weighing only a small fraction of their 500-lb. load, these PSC "Light-Weight" containers not only save handling time but also effect impressive savings in heating time and fuel. Size 24" x 24", they are pinned to trays fitting roller rails. Fabricated of the sheet alloy which best stands the atmosphere and temperature conditions, these boxes have been in continuous 60-hour anneals for a great many months without significant distortion or embrittlement. PSC sheet alloy equipment fabricated for every purpose: annealing and carburizing boxes, covers, baskets, fixtures, retorts, tubes, etc.

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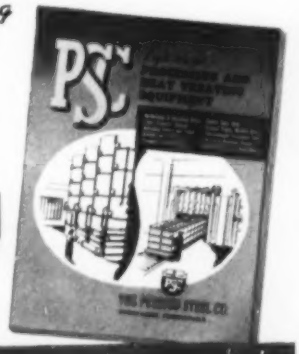


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## Correspondence

*(Continued from p. 116)*

of titanium was obtained by courtesy of the British Non-Ferrous Metals Research Assoc., and a number of microhardness tests were carried out in this laboratory. No difficulties have been experienced, the highest loads obtainable with our apparatus being 3 kg.

Figure 1 is a photomicrograph of one of the indentations and may convince workers in this field that the indentation is perfectly clean. The only unusual feature is the number of striations around the indentation.

May it be suggested that the cleaning indicated with fused silica may be partly responsible for the trouble experienced? Also the surface of the diamond indenter may be considerably harder than the silica. It may have been stuck to the diamond surface or alternatively abraded. Thus the high polish essential for a good indenter could have been destroyed. It should be remembered that the active surface of an indenter, if roughened, will produce considerable friction on making an indentation.

P. GRODZINSKI
Diamond Research Dept.
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NEW YORK CITY and EASTERN PENNSYLVANIA—Gerald B. Duff, 68 Clinton Ave., Newark, N. J.; MICHIGAN—M. C. Schwar, 2970 W. Grand Blvd., Detroit 2, Mich.; OHIO, INDIANA, WEST VIRGINIA, KENTUCKY and WESTERN PENNSYLVANIA—M. L. Snodgrass, 4298 Silsby Road, Cleveland 18, Ohio; NEW ENGLAND—James J. Herkis, 184 Weeden St., Pawtucket, R. I.

## Correction to Article on Titanium

PITTSBURGH

A typographical error appears in our article "Stress Corrosion Cracking of Commercially Pure Titanium" (by George C. Kiefer and Warren W. Harple, and published in the February 1953 issue of *Metal Progress*, p. 74-76). On the last page of the article and in the first column the statement, "Boiling 65% nitric acid, 0.001 to 0.00015 in. penetration per month", should read, "Boiling 65% nitric acid, 0.0001 to 0.00015 in. penetration per month".

WARREN W. HARPLE
Research Laboratory
Allegheny Ludlum Steel Corp.

## Better Iron Smelting

TORONTO, CANADA

The recent technical report by Prof. Robert Durrer issued by the United Nations Economic Commission for Europe emphasizes and makes perfectly clear his reasons for believing that it is very worth-while at the present time to investigate on a large scale the methods of iron smelting which he proposes. Professor Durrer has not only energetically proposed and sponsored the development of new iron smelting processes, particularly fitted to certain raw materials, but he has put into practice his thought-provoking theories. The smelting techniques now in use in the Swiss steel plants which were developed under his guidance and large pilot operations which he supervised demonstrate that under certain conditions the blast furnace is not the only profitable iron smelting process. His answer to the question whether it is worth the money to investigate such operations of these processes now would be 110% "yes". I agree.

The cooperative program being planned in Europe by seven countries under the supervision of O.E.C.E. is the first major step in the direction of outlining the specific advantages and limitations of Durrer's proposals, as well as those of several others. These trials in Belgium and Germany in low-shaft furnaces using both air and oxygen should be of interest in the U. S.

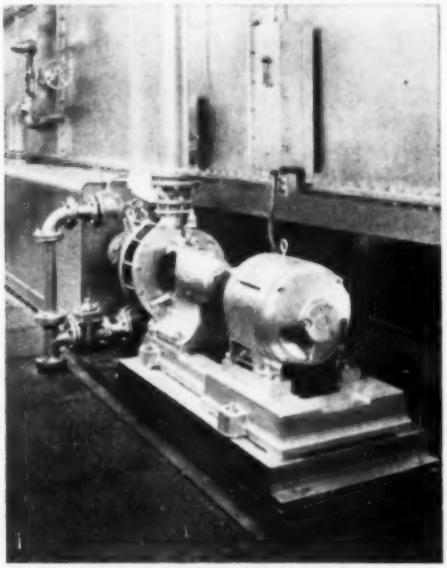
P. E. CAVANAGH
Ontario Research Foundation

# COMPLETE *Finishing* SYSTEMS

**. . . for ENAMELS • LACQUER • PAINT • VARNISH**

Complete Mahon Steel Drum Finishing System installed in the U. S. Steel Products Plant at Dolton, Ill. Similar Mahon Installations, including Metal Cleaning, Rust Proofing and Drying Equipment, are also installed in U. S. Steel Products plants at Sharon, Pennsylvania, and at Alameda, California.

General View of the Complete Mahon Steel Drum Finishing System Installed in the Port Arthur, Texas, Plant of U. S Steel Products Division of the United States Steel Corporation.



One of the large Acid Recirculating Pumps employed in the Pickling and Descaling Stage of the Mahon Equipment illustrated above. Corrosive resistant material is employed for Pumps, all Piping, Solution Tanks, Processing Tunnel Housing and other parts exposed to corrosive materials.

## *Chemically Clean, Scale-Free, Rust Inhibited U. S. Steel Drums Get their Fine Finish in Mahon Equipment!*

In four of its strategically located steel drum plants, The U. S. Steel Products Division of the United States Steel Corporation depends on Mahon Finishing Systems to produce its high quality, 100% scale-free, rust-inhibited steel drums. These drums are absolutely clean, and are protected with a finish which has been processed for maximum adherence and endurance. In the prepainting metal treatment the drum shells and end plates pass through a nine-stage Mahon Cleaning, Pickling and Phosphating Machine—the last stage of which is a chromic acid rinse. These machines are designed with conveyors outside the processing tunnel to protect chain, trolleys and track from the corrosive action of sulfuric acid. Conveyor adapters of noncorrosive material pass through a Patented Mahon Hydro-Hermetic Seal which effectively seals the top of the processing tunnel throughout its entire length. If you are contemplating new finishing equipment, you too, will find Mahon engineers better qualified to determine your equipment requirements and to do the all-important planning and engineering to insure specific results. Regardless of what your product may be, Mahon planned and Mahon built equipment will prove more economical over a period of time. See Sweet's Plant Engineering File for information, or write for Catalog A-653.

**THE R. C. MAHON COMPANY**

HOME OFFICE and PLANT, Detroit 34, Mich. • WESTERN SALES DIVISION, Chicago 4, Ill.

Engineers and Manufacturers of Complete Finishing Systems—including Metal Cleaning and Pickling Equipment, Metal Cleaning and Rust Proofing Equipment, Hydro-Filter Spray Booths, Filtered Air Supply Systems, and Drying and Baking Ovens, Core Ovens, Heat Treating and Quenching Equipment for Aluminum and Magnesium, and other units of Special Production Equipment.

# MAHON

# Personal Mention

Edmund M. Wise

John R. Freeman

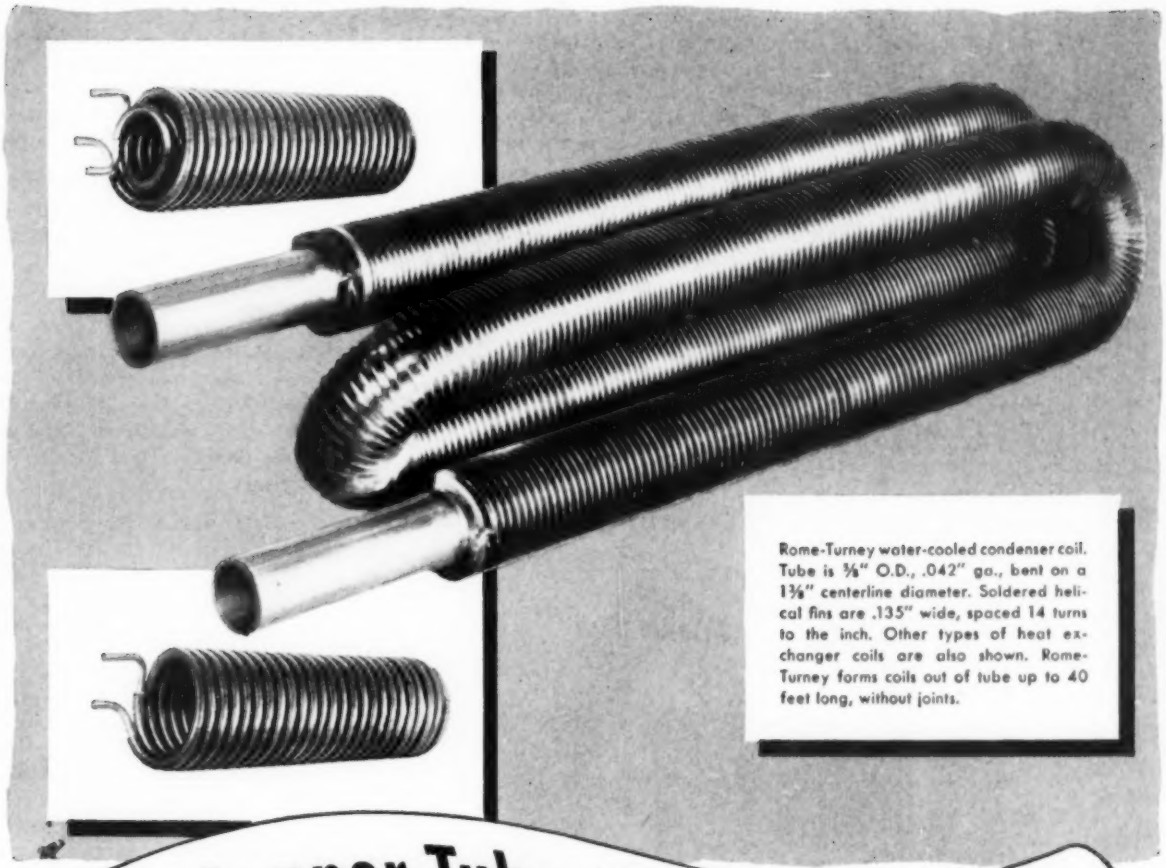
A new member of International Nickel Co.'s Quarter Century Club, EDMUND M. WISE has devoted most of those 25 years to work in the precious metals, hence his present position as head of the platinum metals and electronics section of Inco's development and research division in New York. His early work, however, also embraced nonferrous alloys, including those for high temperature use. An intensive researcher, he holds a large number of patents relating principally to metallurgical processes and rare metal alloys. Among his many capabilities is writing: He is editor of the book "Properties of the Platinum Metals and Their Alloys", is author of a number of papers on nickel alloys and the platinum metals, also editor of the precious metals section of "The National Metals Handbook" and the platinum metals section of "Modern Uses of Nonferrous Metals". He is active in many professional societies, among them being the New Jersey Mineralogical Society, American Institute of Mining and Metallurgical Engineers, and is past chairman of the Institute of Metals Division and the Rare and Precious Metals Committee of AIME. He is also past chairman of the New York Chapter. A native of Chicago, he spent his early life in Fond du Lac, Wis.

In 1895, John Ripley Freeman, then residing in Winchester, Mass., was already well launched on a distinguished career. On being apprised of the birth of a son, he promptly gave the boy his own name and JOHN R. FREEMAN, JR., has been among us from that day. Soon after that the family removed to Providence where the boy grew up in a normal manner and graduated from M.I.T. in 1916. A summer with General Abrasive Co. gave him all he felt he needed of the glamour of Niagara Falls, and he was off that autumn with his father for an inspection of the Grand Canal of China. Returning, he joined the Bureau of Standards where there was, at that time, a goodly company of young men with notable futures in store. The work there suited him so well that, in 1921, he went as a research exchange worker for a turn in the National Physical Laboratory, Teddington, England, then under the aegis of the incomparable Walter Rosenhain. But, by 1930, being then something of a patriarch, 13 years at the Bureau seemed long enough and, accepting a place on the technical staff of The American Brass Co., he was glad to move his family to Connecticut. After that the wheel turned rather fast. Four years later he became assistant technical manager and, in another four years, in 1938, he was head of the department, occupying the chair of the late W. H. Bassett who had beckoned him from the Bureau. As technical manager of The American Brass Co., for the next 15 years he directed the technical aspects and activities of the Company until now, in 1953, the stature of both job and man is recognized by the appointment of vice-president – metallurgy and research. Still in the prime of his vigor, the future looks attractive.

**Irving A. Dickter**, formerly with Goodman Mfg. Co., Chicago, as chief metallurgist and chemist, is now employed by Cincinnati Milling & Grinding Machines, Inc., Cincinnati, Ohio, as supervisor of the flamatic laboratory.

**P. G. Patch** has left Goodyear Aircraft Corp. to become production engineer at McCulloch Motors Corp., Los Angeles.

**Fritz V. Lenel** of the metallurgical engineering faculty at Rensselaer Polytechnic Institute is heading up three research projects for defense agencies, involving the expenditure of $90,000 at the Institute. The Bureau of Ships, Navy Dept., has renewed for a second year its contract with the Institute for investigation in the field of cemented carbides. The Bureau of Ships is interested in developing cemented carbides which are low in strategic metals, such as cobalt. Dr. Lenel's program of research for Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, provides for an extensive investigation of the use of aluminum powder in fabricating metal parts. He is also engaged in research for the Rochester Ordnance District, Rochester, N. Y., investigating the properties of iron powders and how they affect the strength of metal parts fabricated from the powders. Dr. Lenel is an authority in powder metallurgy. Last summer in Austria he presented one of the major papers before an international conference on this field of metallurgy. He has recently returned from Los Angeles where he presented a paper on powder metallurgy at a meeting of the American Institute of Mining and Metallurgical Engineers.



Rome-Turney water-cooled condenser coil. Tube is ⅜" O.D., .042" ga., bent on a 1⅜" centerline diameter. Soldered helical fins are .135" wide, spaced 14 turns to the inch. Other types of heat exchanger coils are also shown. Rome-Turney forms coils out of tube up to 40 feet long, without joints.

# For Copper Tube that can be BENT

# Rome-Turney sees REVERE

Most of the Revere Metals are fabricated by usual methods into conventional products. Some of them, however, appear on the market in forms that are unusual and possess special advantages. Take these helical-finned copper coils produced by the Rome-Turney Radiator Co., Rome, N. Y. It takes extra skill to produce coils with such small radii. The company can produce the coils shown on a commercial basis, for use in air conditioning apparatus, air compressors, and general heating and cooling applications where compactness plus high heat transfer rates are essential.

How it is possible to make such tight turns is Rome-Turney's secret. Revere does not share in it, nor does Revere want to reveal a secret of its own, which is how we turn out copper tube in a special bending temper for an application such as this. All we can say is that the two methods dovetail very nicely. If you need copper tube that can be bent easily, and offers you as well the advantages of corrosion resistance, high heat transfer, easy joinings, see Revere. We also make copper pipe, tube in copper alloys, aluminum alloys, and electric welded steel tube. If required, the Technical Advisory Service will gladly collaborate with you, as it has with Rome-Turney, on selection and specification matters. Get in touch with the nearest Revere Sales Office.

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**SEE REVERE'S "MEET THE PRESS" ON NBC TELEVISION EVERY SUNDAY**

## Personals

**John A. Deitrich** has been appointed president of Hind Steel Co., Inc., Union, N. J. Formerly divisional manager of the Carpenter Steel Co., he is a pioneer metallurgist in welded stainless steel tube.

**Kenneth J. Humberstone** has been named a vice-president at American Tank & Fabricating Co., Cleveland. He is in charge of engineering, manufacturing and sales.

**Leonard W. Kates** has been promoted to manager, central engineering metallurgy, atomic energy division, Sylvania Electric Products Inc., Bayside, N. Y. He was formerly section head of the metallurgical laboratory.

**Thomas L. Moore**, past chairman of the Baltimore Chapter, formerly with Rustless Iron and Steel Corp., Baltimore, and Armco Steel Corp., Philadelphia, has become affiliated with Tubesales in Los Angeles as manager, technical service.

**B. Dixon** was recently appointed vice-president and general manager of Dominion, Scott, Barron Ltd., and director of Dominion Wheel & Foundries Ltd., Canada. He is vice-chairman of the Ontario Chapter.

**Carson B. Bartholomew**, after two years duty with the Air Force in Alaska, has accepted a position as metallurgist with Aluminum Co. of America, assigned to the Lafayette, Ind., Works.

**John H. Cox** has recently been promoted from supervisor of the Barberton (Ohio) Works, Babcock & Wilcox Co., to department head of the tube division, Texas Works, at Paris, Texas.

**Austin V. Jackson**, previously with Glenn L. Martin Co. and Boeing Airplane Co., is now chief of the materials and process unit, Philadelphia regional office, Eastern Air Procurement District.

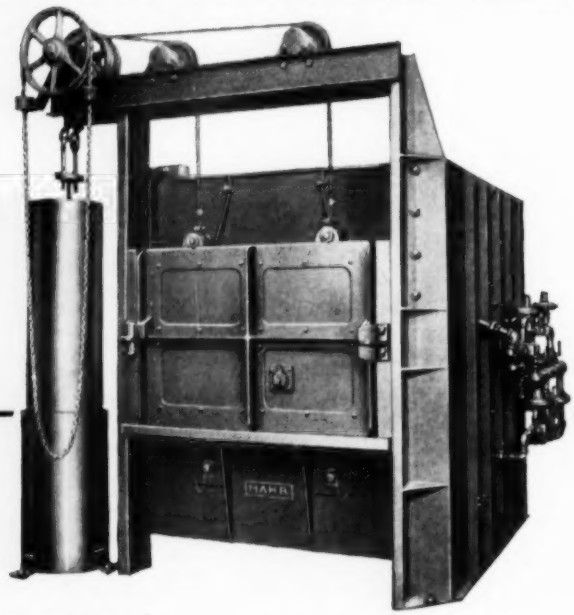
**Maurice J. Day** has been promoted to assistant director for program development at Armour Research Foundation of Illinois Institute of Technology. As metals expert, Dr. Day will coordinate the program development activities of the Foundation's eight departments. He joined the Foundation in 1952 as manager of its materials and processes division after 15 years service with U. S. Steel. During World War II he was consultant to Detroit industries using steel in ordnance work and to the U. S. Chief of Ordnance in connection with the nation's steel-helmet program. Currently he is a member of the Military Ordnance Department Metallurgical Advisory Committee for Large Guns and the American Ordnance Association Committee for Small Arms and Ammunition. He also is chairman of 's Education Committee and is a member of many professional societies.

**John F. O'Keefe** has been transferred from regional sales engineer, New York office of Reynolds Metals Co., to assistant to vice-president of product and market sales development in Louisville, Ky.

**Carl T. Kunze** has resigned as research metallurgist with American Can Co., Maywood, Ill., to become assistant to vice-president at Arlington Corp., St. Paul, Minn.


UNIT CONSTRUCTED*

**MAHR GAS FIRED HEAT TREATERS**



*A 1' Sectional Unit for Each Foot of Effective HEARTH LENGTH

*Can be provided with motorized or pneumatic door*

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CLOSE, ACCURATE CONTROL AND UNIFORMITY AT 1000°-1800° F.

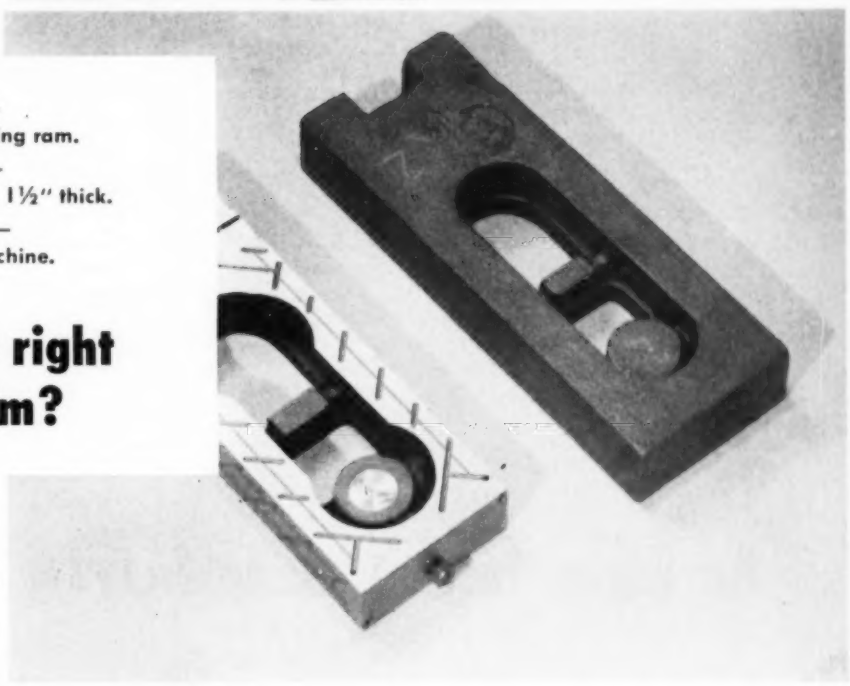
**INSTALL** a Mahr General-Purpose Heat Treater and get the benefit of the latest in furnace construction. Check these advantages: (1) improved design saves valuable floor space, (2) quick heatup increases production, (3) uniform temperature plus complete combustion give better product, (4) accurate control assures product uniformity, (5) Mahr method of firing needs minimum fuel consumption.

**AVAILABLE** Under or Over and Under Fired. Write for Bulletin 120-B. Bid requests should specify: (1) over and under firing or under only, (2) whether low or high pressure gas and at what pressure, (3) BTU content of gas.

MAHR MANUFACTURING CO.
DIVISION OF DIAMOND IRON WORKS, INC.
MINNEAPOLIS, MINNESOTA, U.S.A.

1802 N. 2nd STREET

**PRODUCT—**
**Casting for reciprocating ram.**
**MATERIAL—**
**High-strength cast iron 1½" thick.**
**EQUIPMENT—**
**220 kv x-ray machine.**



# What's the right X-ray film?

## KODAK INDUSTRIAL X-RAY FILM, TYPE K

This casting, worth about $2, is headed for machining, heat treating and scraping worth $375. It's no time to take a chance on hidden faults.

So the radiographer checks each casting and discards the unsound.

For these radiographs he uses 220 kv at a distance of 40 inches, lead screens, and Kodak Industrial X-ray Film, Type K—the right choice for this thickness of iron and x-ray equipment.

### THERE'S A RIGHT FILM FOR EVERY PROBLEM

Whatever your radiographic problem, you'll find the best means of solving it in one of Kodak's four types of industrial x-ray film. This choice provides the means to check castings and welds efficiently, offers optimum results with varying alloys, thicknesses and radiographic sources.

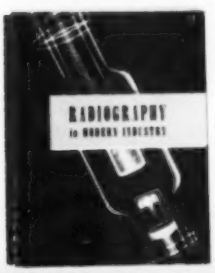
**Type K**—has medium contrast with high speed. Designed for gamma ray and x-ray work where highest possible speed is needed at available kilovoltage, without use of calcium tungstate screens.

**Type A**—has high contrast and fine graininess with adequate speed for study of light alloys at low voltage and for examining heavy parts at intermediate and high voltages. Used direct or with lead-foil screens.

**Type M**—provides maximum radiographic sensitivity, with direct exposure or lead-foil screens. It has extra-fine grain and, though speed is less than Type A, it is adequate for light alloys at average kilovoltages and for much million- and multi-million-volt work.

**Type F**—provides the highest available speed and contrast when exposed with calcium tungstate intensifying screens. Has wide latitude with either x-rays or gamma rays when exposed directly or with lead screens.

## Radiography... another important function of photography




### RADIOGRAPHY IN MODERN INDUSTRY

A wealth of invaluable data on radiographic principles, practice, and technics. Profusely illustrated with photographs, colorful drawings, diagrams, and charts. Get a copy from your local x-ray dealer—price, $3.

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## Personals

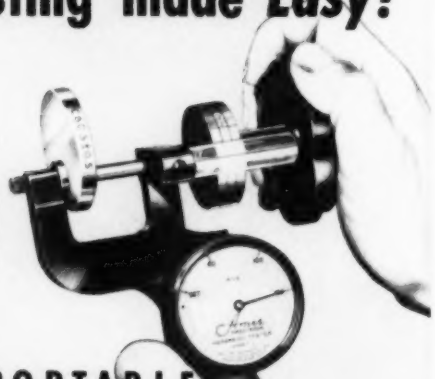
**Harry I. Dixon** has been appointed New England representative of the Alloy Precision Casting Co., Cleveland, with offices in Brookline, Mass. Mr. Dixon, a graduate of the University of Michigan, is widely known in the metallurgical field. Following employment as metallographer and metallurgist for General Motors Research Corp., Crucible Steel, and New Jersey Zinc Co., he served as vice-president of the Park Chemical Co. and Sterling Alloys Co.

**Eugene H. Kinelski** has resigned his position as materials engineer in research and development at Pullman-Standard Car Mfg. Co., Hammond, Ind., to accept a fellowship sponsored by the American Iron and Steel Institute at Mellon Institute, Pittsburgh, Pa.

**G. R. Caskey, Jr.**, who recently obtained an M.S. degree from Massachusetts Institute of Technology, is employed in the metallurgy section, technical division, Savannah River Plant, E. I. duPont de Nemours & Co., at Aiken, S. C.


**Hardness testing made *Easy!***

**Save Time!**
**Test Accurately!**



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**HARDNESS TESTERS**

Frequent hardness testing of metals before and during fabrication and after heat treating is essential today for best results.

Ames Portable Hardness Testers answer the need for a light weight, accurate, dependable tester that may be carried to the work for on-the-job testing. They are easy to use, require no skill, and get speedy, accurate tests wherever the work may be—no delays, no cutting off specimens—no waiting for laboratory tests.

Besides testing flats, rounds, tubing, etc. Ames Hardness Testers make tests that otherwise would be impossible, such as large gears, knives, saws, blades, struts, frames and assembled parts. Thousands are in use paying for themselves over and over again in time and materials saved.

*Send for literature or ask for demonstration in your plant. No obligation.*

**AMES PRECISION MACHINE WORKS**
*Makers of Ames Precision Lathes and Bench Millers*
**Waltham 54, Massachusetts**


**Victor Brown**, formerly assistant to the president of Kropp Forge Co., Chicago, has been elected a vice-president. A member of the board of directors since 1947, he joined the company in 1942 as chief metallurgist and was appointed technical director in 1945. Prior to joining Kropp Forge, Mr. Brown served eight years in the metallurgical department of Republic Steel Corp., Chicago. He is a past chairman of the Chicago Chapter.

**Donald H. Turner**, having been released from the Army after serving at Frankford Arsenal as a metallurgical research assistant, has joined Armour Research Foundation, Chicago, as assistant metallurgist.

**Clarence J. Burke** has accepted employment as a metallurgist for AiResearch Mfg. Corp., Los Angeles. He was previously research metallurgist for American Steel Foundries at East Chicago, Ind.

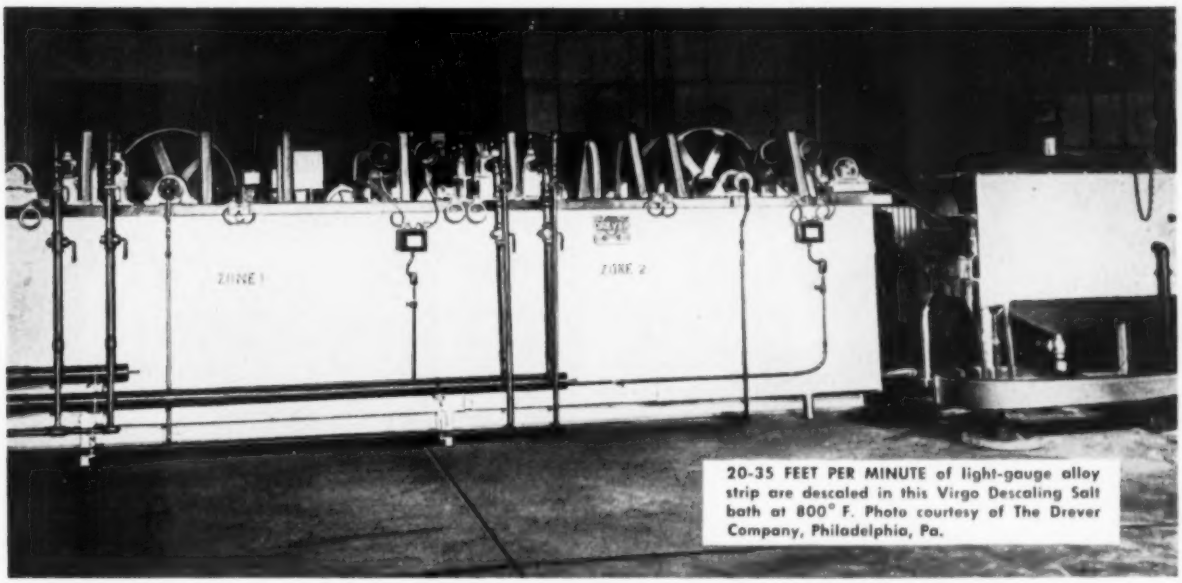
**D. C. MacCullum** resigned as vice-president and managing director of Charles Warnock and Co., Ltd., and obtained federal charter in the name of Racey, MacCullum and Assoc., Ltd., Montreal, Canada, of which he is the president. The new company is engaged in industrial appraisal, soils engineering, inspection, expediting and consulting work.

**Mervin T. Rowley**, formerly assistant chief metallurgist at Ohio Injector Co., Wadsworth, Ohio, has accepted a position as principal metallurgist at Battelle Memorial Institute, Columbus, Ohio.

**J. F. Simpson**, formerly research metallurgist with the A. F. Holden Co., Detroit, is now research engineer in the minerals processing division, Battelle Memorial Institute, Columbus, Ohio.

**F. J. Shortsleeve**, having recently finished work toward a Ph.D. degree in metallurgy at Case Institute of Technology, is employed as a member of the reactive metal group of Union Carbide and Carbon Research Labs., Niagara Falls, N. Y.

**Joseph J. Chase**, former research engineer at Thompson Products, Inc., Cleveland, has been appointed chief engineer at JeTool, Inc., an affiliate of the Jet Die and Development Co., Cleveland.



**20-35 FEET PER MINUTE** of light-gauge alloy strip are descaled in this Virgo Descaling Salt bath at 800° F. Photo courtesy of The Drever Company, Philadelphia, Pa.

## *HOW TO*

# DESCALE 5½ MILES OF STRIP PER DAY

### You can get clean bright surface in ONE operation with VIRGO® DESCALING SALT

Straight chrome and chrome nickel strip flow through this continuous descaling-annealing unit, at 25-35 feet per minute—about 5½ miles per 24 hour day.

The light-gauge strip is descaled in one pass through a bath of molten Virgo Descaling Salt at 800° F., after annealing. The process yields a chemically clean, bright surface with no pitting, etching or metal loss.

Large or small, your plant can show real production-time savings with the Hooker Process using Virgo Descaling Salt, or with the Virgo Molten Cleaner process. Use these processes on stainless and alloy steels; castings; forgings; fabricated parts; material to be salvaged. Both processes are non-electrolytic . . . non-toxic . . . employ simple equipment . . . do not require close supervision . . . are easily adapted to your production methods. For full details, mail coupon or write us today.

### For Fast, Safe, Low-Cost DESCALING

**VIRGO® DESCALING SALT**—Producers and fabricators of stainless and alloy steels use Virgo® Descaling Salt to quickly remove scale produced by hot rolling, forging, extruding, casting, annealing.

**VIRGO® MOLTEN CLEANER**—Quickly, positively desands and degraphitizes castings; removes grease, dirt, chemicals, paint, enamel, rubber atmospheric corrosion and other impurities.

**BOTH HOOKER PROCESSES** are backed by 15 years' experience in salt bath descaling and cleaning. Engineering, research and on site operating assistance are part of our service.

**SEND FOR THESE BULLETINS**
They tell the whole story on Virgo Descaling Salt and Virgo Molten Cleaner—what they are, how they work, their advantages, equipment involved, and the Hooker services you enjoy as a user of the process.

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*telling the story of 'dag' dispersions*

# Here is a Lubricant that Can't Burn Off, Flake, or Gum Up

**'dag'** dispersions of colloidal graphite form microscopically thin *dry lubricating films* which fight friction beyond the burning-points of most oils. They cannot burn off, flake, or gum up at ordinary metalworking temperatures. These dry films are unaffected by heat up to 750°F.... under some conditions up to 3,000°F.

**'dag'** dispersions can profitably be used in stamping, deep drawing, piercing, casting, forging, stretch-forming, and wire drawing operations. They lessen die wear, produce smooth parting and clean surfaces, minimize scaling and sticking, reduce tearing and rippling, and assure uniform dimensions.

For more details on metalworking applications, write for Bulletin No. 426-10E.

*Dispersions of molybdenum disulfide are available in various carriers. We are also equipped to do custom dispersing of solids in a wide variety of vehicles.*

dag DISPERSIONS

**Acheson Colloids Company,** Port Huron, Mich.
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*try 'dag' resin-bonded dry films for permanent lubrication*

# FERROVAC* 4340

## *for Alternating Stresses*

**TESTS** on vacuum-cast metals show improved fatigue and stress properties. The extraordinary cleanliness and freedom from gases of Ferrovac 4340 are illustrated in the photomicrographs above.

We believe manufacturers using 4340 in alternating stress applications will find these improved characteristics of great importance in increasing product life.

Commercial quantities of vacuum-melted metals are now being produced in Vacuum Metals Corporation's new expanded facilities. On order Vacuum Metals will supply test or commercial quantities of vacuum-cast metals to customer specifications.

**VACUUM-MELTED METALS AVAILABLE AT VMC:**

FERROVAC® 52100
FERROVAC® 4340
CUPROVAC® E
(Electronic-grade Copper)
NIVAC®
(Nickel and Alloys)

Other metals or alloys vacuum-cast to customer specifications.

HIGH PURITY METALS
HIGH VACUUM CASTING
SPECIAL ALLOYS
GF (Gas Free) METALS

VMC

**VACUUM METALS CORPORATION**

*Subsidiary of National Research Corporation*

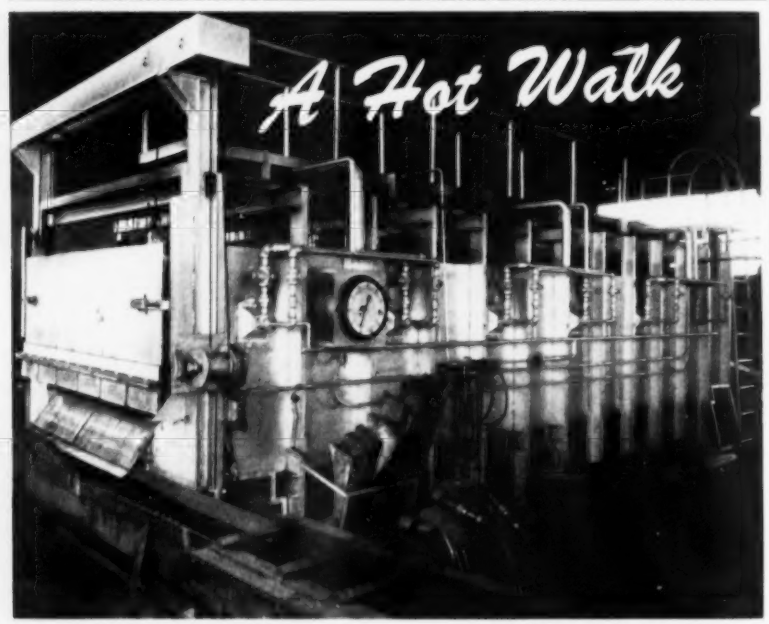
70 MEMORIAL DRIVE, CAMBRIDGE 42, MASSACHUSETTS

## Personals

**Edward A. Macke, Jr.,** joined the S. H. Bell Co., Pittsburgh, last fall and is selling metallurgical products produced by the Tennessee Products & Chemical Corp. Mr. Macke was formerly with Jones & Laughlin Steel Corp., Pittsburgh.

**H. R. Kampe**, formerly metallurgist at Percussion Div., Chicago Pneumatic Tool Co., Utica, N. Y., is now executive metallurgist at Joe Martin Co., Detroit.

**Lester A. Shea**, general sales manager of Lindberg Engineering Co., Chicago, has returned after eight months in Washington as industrial representative in the National Production Authority. In this assignment, Mr. Shea represented the industrial furnace, high frequency and heating device industry. Upon his return to Lindberg, he was designated to head the expansion plans and moving of Lindberg's Air & Hydraulic Div. to a new location. Mr. Shea is former secretary-treasurer of the Chicago Chapter.


Eighty-five hundred pounds of flat bar stock an hour gets a hot walk through this Jet Combustion furnace, built in 1946 . . . and still walking.

JET custom engineered walking beam furnaces give you the right furnace for the job you want to do ***today*** . . . pre-heat, harden or draw . . . they are an economical method of handling many types of work.

JET custom engineering also gives you flexibility . . . gets you set for the job you may have to do ***tomorrow.*** For instance, this furnace was originally rated at three thousand pounds an hour, but as "know how" was gained in the plant, the furnace capacity was boosted and has maintained ***eighty-five hundred pounds*** an hour with no changes or additions except increased fuel input.

JET custom engineering gives you comparably low initial prices ***plus*** long run economies.

***It's a good bet to see JET***

**JET COMBUSTION, INC.**
**INDUSTRIAL FURNACES • EQUIPMENT ENGINEERS**
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**Alvin W. Czanderna** was discharged from the U. S. Air Force after 20 months service as a project engineer in the metallurgy branch, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, and has accepted a position with the Aluminum Co. of America Research Laboratories, New Kensington, Pa., as a junior research metallurgist.

**Mark A. Wallesz** is now employed as a metallurgical engineer in the engineering division, Chrysler Corp., Detroit.

**Frank J. Pryatel**, formerly chief metallurgist of the South Bend, Ind., plants of the Oliver Corp., is now methods and standards superintendent at the Cleveland plant.

**G. D. Ries** has been transferred to Paris, Tex., to head a laboratory group at the new fabrication plant of the Babcock & Wilcox Co. He was formerly at the Barberton (Ohio) Works, engaged in electrode research and development.

**Claude Belleau** is now metallographer and metallurgical investigator at Sorel Industries, Ltd., in Sorel, Quebec, Canada.

**George Hoppin III** has been released from service with the U. S. Army and has accepted a position as metallurgist with the Aircraft Gas Turbine Div., General Electric Co., at Evendale, Ohio.

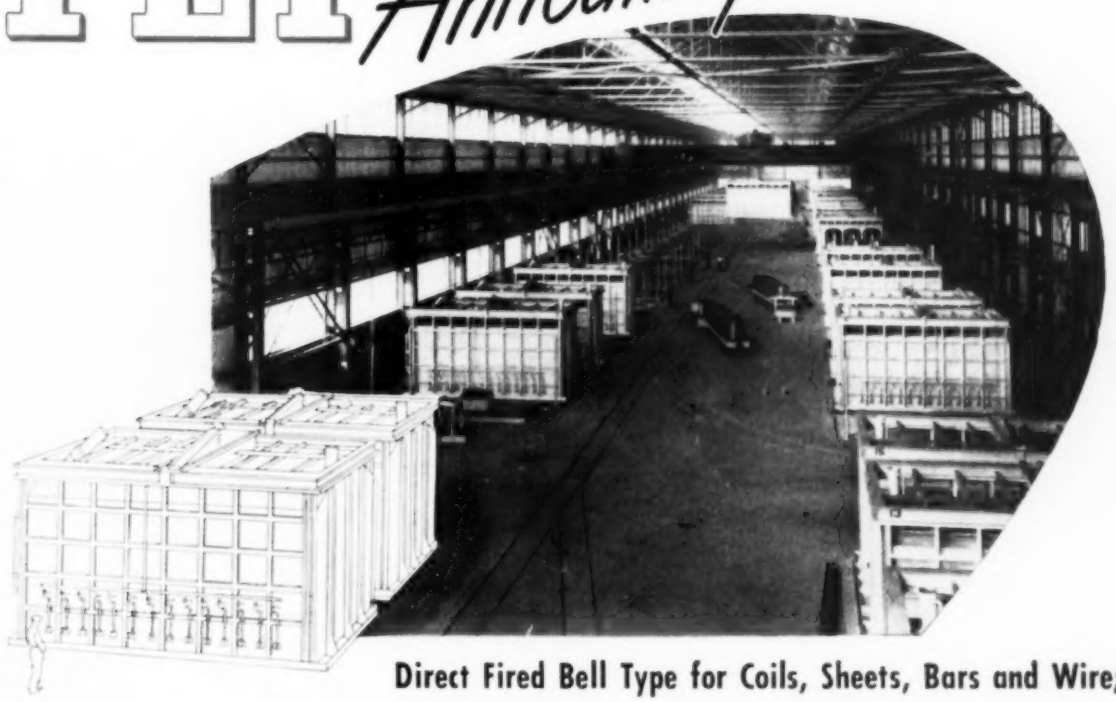
**Henry R. Friedberg**, formerly manager of technical service at F. C. Russell Co., Cleveland, has joined the technical department of Osborn Mfg. Co., Cleveland, as development engineer on surface finishes.

**Joe B. West** has joined the sales and service division of Kelite Products, Inc., Los Angeles, after 13 years with Douglas Aircraft Co., Inc., most recently in charge of the aluminum and steel heat treat department in the Tulsa, Okla., division.

**Edward H. Berry** has been promoted to foundry manager and chief metallurgist and **Henry J. Kelly** has been promoted to chief engineer at Dodge Steel Co., Philadelphia.

**Samuel B. Prellwitz**, formerly process metallurgist with U. S. Steel Corp., Clairton (Pa.) Works, is now control metallurgist at the Fairless Works, Morrisville, Pa.

# F·E·I· *Annealing Furnaces*



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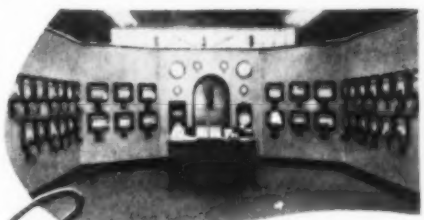

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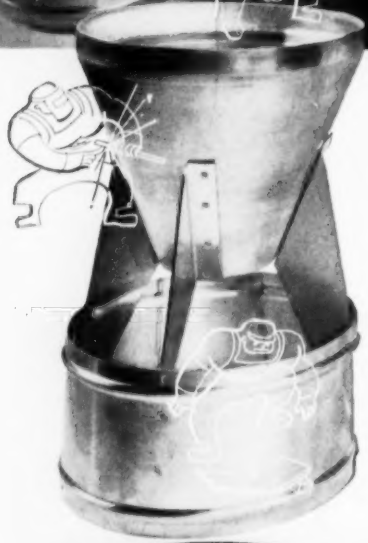

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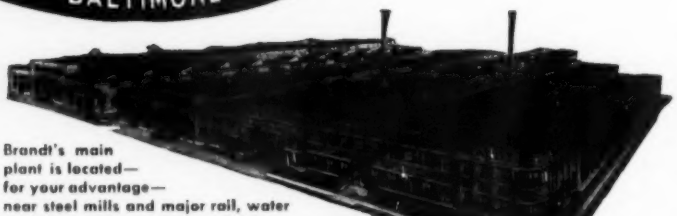

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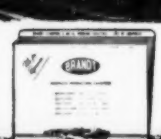

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**CHARLES T. BRANDT, INC. Baltimore 30, Md.**


## Cold-Flow Pressing of Steel*

IN THIS SECOND and concluding article the author describes the practical application of the process. He also points out some of its limitations and outlines the principles of tool design for cold-flow pressing.

Flow-pressing was first introduced as an alternative to deep-drawing, since it enabled reductions up to 80% to be obtained in a single stroke, thereby saving 2 to 3 redrawing operations, intermediate annealing and pickling. Thick-bottomed cup-shaped bodies with substantial height-to-diameter ratios can be produced by this method with maximum economic advantage. With shallow cups (height : diameter $<1$) the advantages of the process cannot always be properly utilized because of the difficulty of obtaining clean shearing of short pieces of wire or rod.

Many solid shapes are also manufactured by the flow-pressing process which permits the saving of much material and machining work. For example, at one time shoulder pins had to be machined from free-cutting, bright-drawn stock because the heads required too large a volume of metal for successful upsetting. By cold-flow pressing, a pin about 2 in. long with a shaft of $\frac{1}{2}$ in. diameter, $\frac{5}{8}$-in. diameter head, and a 1-in. diameter shoulder at midlength, can be made in two blows on a horizontal, automatic 200-ton bolt press. Hot-rolled coil stock (pickled and phosphate-coated) about $\frac{43}{64}$ in. diameter is used, and since all rough machining is eliminated, the saving in material amounts to 70%. In the first operation, the shaft of the pin is formed by forward extrusion of a blank $1\frac{9}{16}$ in. long. In the second, the formed shaft is inserted into the female dummy die, while the countersunk forming tool is mounted on the movable ram; sizing of the head is done by reversed extrusion during the working stroke of the press; also, the pressure causes some material to flow sidewise in the countersunk die, thereby producing the shoulder.

A similar method is used to form 0.22-in. diameter steel wire of 1.1%

*(Continued on p. 132)*

*Digest of "The Development and New Applications of Cold-Flow Pressing of Steel, Part II", by K. Sieber, *Draht*, December 1952, p. 29-33. For digest of Part I see *Metal Progress*, January 1953, p. 186.

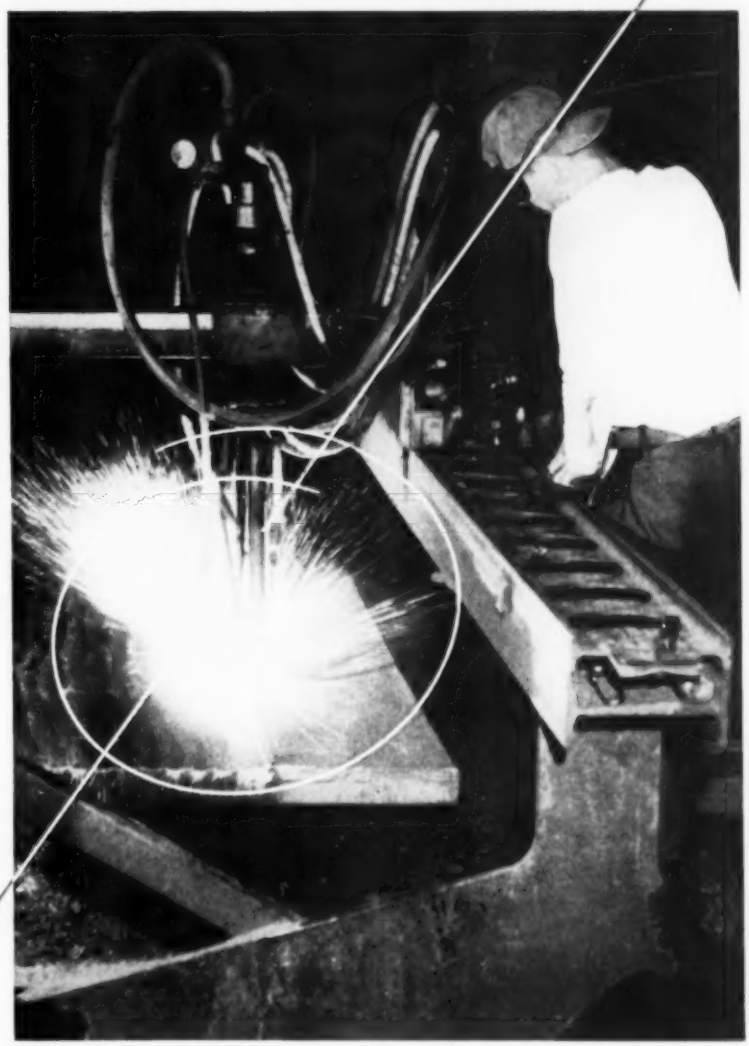
# How Oxygen...and LINDE SERVICE*

## SAVED $700,000 FOR ONE STEEL COMPANY

"Burning the unburnable" was the problem that faced producers of stainless steel. This steel resisted scarfing and cutting—even with the intense heat of the oxy-acetylene flame.

Doing this work by mechanical methods meant sky-high costs. But that looked like the only answer—until LINDE SERVICE took a hand with the problem.

Working in the laboratory and in the field, LINDE engineers developed powder cutting and scarfing. By adding powdered metal to the oxygen flame, stainless steel was scarfed and cut with ease and speed.



**LINDE SERVICE IN ACTION!** Powder cutting is saving this company alone over $700,000 per year in the production of stainless steel. And they're making a better product.

This is but one example of how LINDE customers are saving millions of dollars each year through LINDE SERVICE. If you use oxygen, let us tell you how LINDE SERVICE can save you time and money, too.

* **LINDE SERVICE** is the unique combination of research, engineering, and over 40 years of accumulated know-how that is helping LINDE customers save money and improve production in their uses of oxygen and oxy-acetylene processes.

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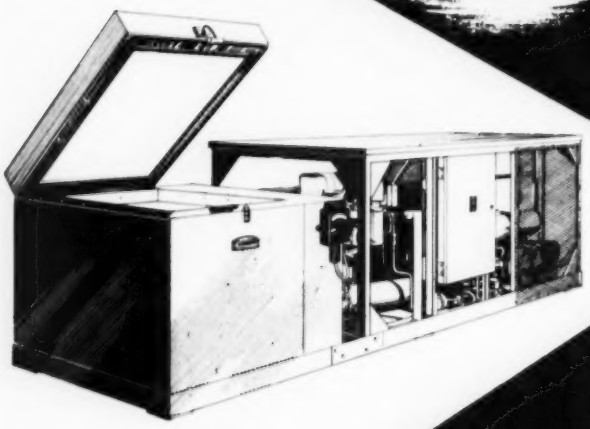

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## Cold-Flow Pressing of Steel

*(Continued from p. 130)*

carbon into firing-pin blanks for rifles. This simple component could not be produced by any other method of plastic forming because of its relatively large "head" (0.22 in. diameter and $\frac{7}{8}$ in. long in the finished condition).

Total reduction for the shaft is about 60%.

In flow-pressing there is a lower limit for the absolute dimensions of the formed part, below which the method cannot be applied. This is due to the circumstance that with decreasing diameter, the cross section is reduced much faster than the peripheral area, so that the power required to overcome contact friction increases very rapidly to the extent that the thin tools become incapable of transmitting the relatively high loads. The firing blanks just mentioned are about the absolute low limit of what can be pressed. For cup-pressing, the economic punch diameter minimum is $\frac{3}{8}$ to $\frac{5}{8}$ in.

Best material, design, heat treatment, and workmanship are essential to secure proper performance of the highly stressed tools. Dies, punches, and ejectors should be as small and short as practicable, and easily changeable. To allow for tool wear, the pressing diameters should be as wide as possible. A separate calibrating operation is advisable for parts of very exacting dimensions, and lathe finishing is best to get less than 0.004-in. eccentricity.

The high maximum load on the die bore, when higher internal pressures occur, may result in permanent expansion of the die, and in cracking of the bore surface. An increase of the outer diameter of die above a certain limit leaves the peak stress on the inner surface practically unaffected. This peak can be effectively reduced only by "armoring" the die by one or even two concentric sleeves shrunk on it. The substantial compressive prestress produced in the inner bush is subtractive to the tangential tension caused by the working pressure. When the optimum diameter proportions and shrinkage prestresses are accurately assessed, the load capacity of nonarmored dies as compared with single or double-armored is as 1 : 1.45 : 1.8.

N. H. Polakowski

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"The longer length of Asarcon bronze saves a lot of handling in machining operations and also cuts down scrap losses."

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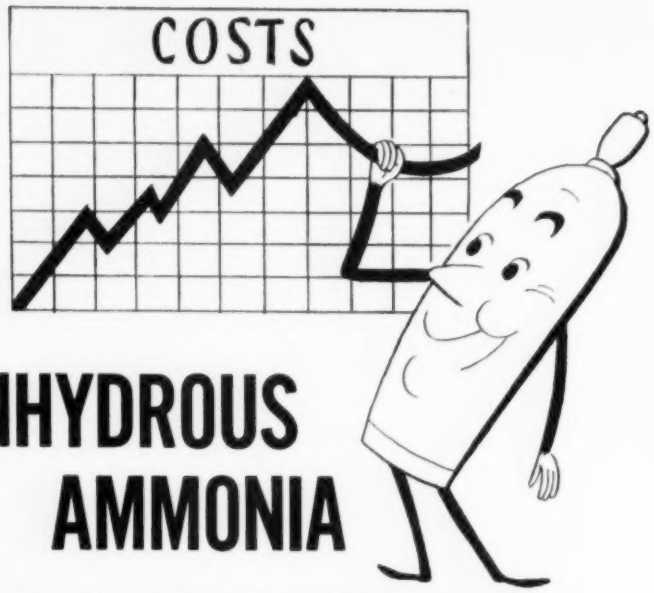


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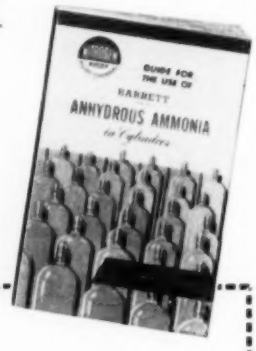


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## Boron in Structural Steels*

THE EFFECT OF BORON additions to a carbon steel and three types of alloy steels was determined for commercial melts made in an acid induction furnace. The melts were deoxidized with aluminum before the boron addition; the latter addition being made to one half of each melt, with the untreated portion being used as basis for comparison of the mechanical properties for the treated and nontreated steels. Boron additions were made in the ladle and all of the steels were cast into 180-mm. (7-in.) diameter billets.

After the billets of the carbon steel (37MnSi5; 0.33% C, 1.15% Si, 1.20% Mn) were forged into rods of various sizes, hardenability was determined from end-quench tests. Austenitizing temperatures used were 1455, 1510, 1560, 1615 and 1670° F.

Boron had no apparent effect on the hardenability of samples austenitized at 1510° F., whereas the effect was significant on samples heated to 1560° F. The improvement in hardenability was more noticeable for the 1615° F. samples, and this was even greater than for specimens austenitized at 1670° F.

It was concluded from the end-quench curves derived from these tests that an addition of 4 lb. "Silcaz" per ton of steel (approximately 0.001% boron) is sufficient to cause an improvement. The possibility of improving the hardenability of these steels through such small additions of boron is definitely indicated. It is true that the extra silicon introduced in the steel with the boron addition is responsible for some of the improved hardenability; however, this additional amount of silicon certainly cannot be responsible for the entire effect.

Boron appears to retard the beginning of the transformation but does not seem to have any marked effect on the end of the transformation. In this respect boron differs from other alloying elements.

Taking a 95% martensite structure to correspond to Rockwell C-50 and a 50% martensite structure to correspond to Rockwell C-40, the

*(Continued on p. 138)*

*Digest of "Experiences With Boron Additions to Alloy Structural Steels", by H. Krainer and M. Kroneis, *Stahl und Eisen*, Vol. 72, Dec. 12, 1952, p. 1652-57.

# G-E Pyrometers Assure Reliable Control With Easy Maintenance, Sturdy Construction

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The instrument mechanism is built around a $3\frac{1}{4}$ lb. Carboloy® alnico permanent magnet. The armature has spring-mounted jewel bearings to provide a high resistance to shock and vibration, thus assuring sturdy construction.

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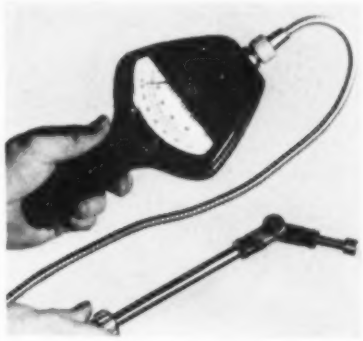

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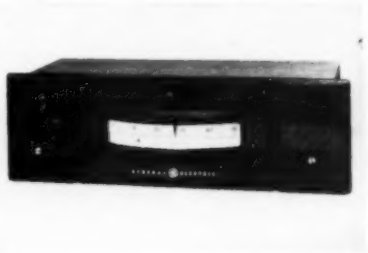

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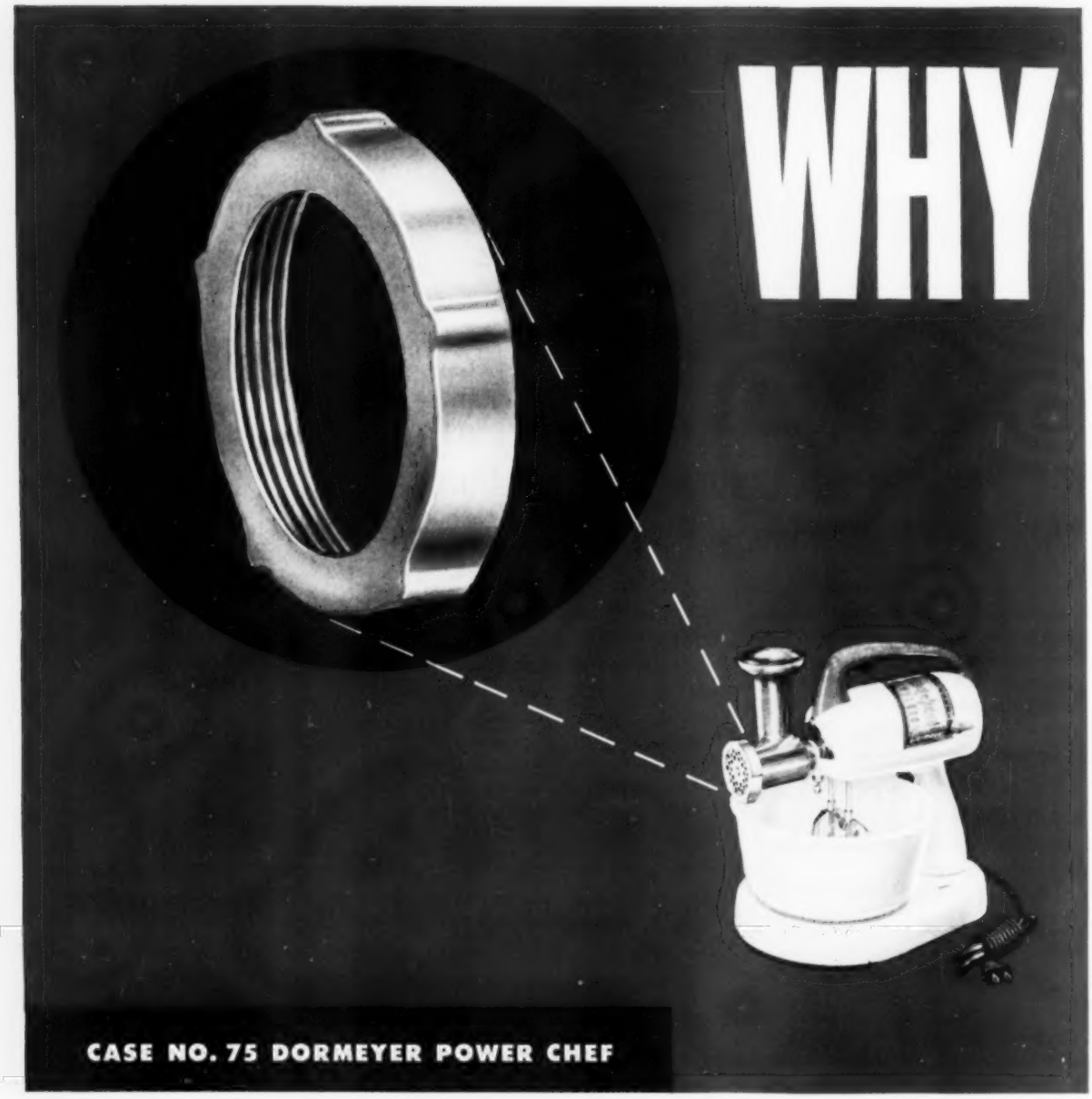


Even small parts can help reduce production costs and increase sales appeal. This aluminum nut for the grinder attachment of the popular Dormeyer Power Chef is a small part with a big job. Stock for the nut is Reynolds Aluminum drawn round tubing. Manufacturing costs are lowered because aluminum is an economical material. It is readily worked on automatic screw machines and requires no costly finishing operations.

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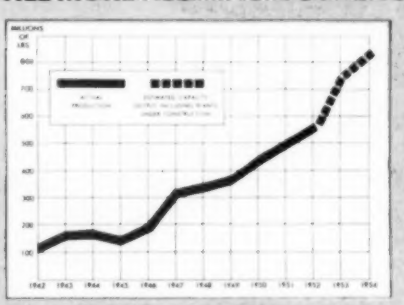

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## Boron in Structural Steels

*(Continued from p. 134)*

authors compute the ideal critical diameters from the end-quench data. According to the principles outlined by M. A. Grossmann (*Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 150, 1942, p. 227-259), the hardenability factor for Rockwell C-50 proves to be 1.5 and for C-40 it comes to 1.4. The higher hardenability factor for the higher hardness is in accord with the idea expressed previously that the influence of boron is strongest at the start of the transformation.

The accepted end-quench values for boron-free 37MnSi5 steel are shown as a band and, on comparing the data obtained in this experiment, it was found that the curve for the boron-containing samples fell just within its upper boundary. From this it was concluded that the "condition" of the steel was fundamentally altered by the boron addition.

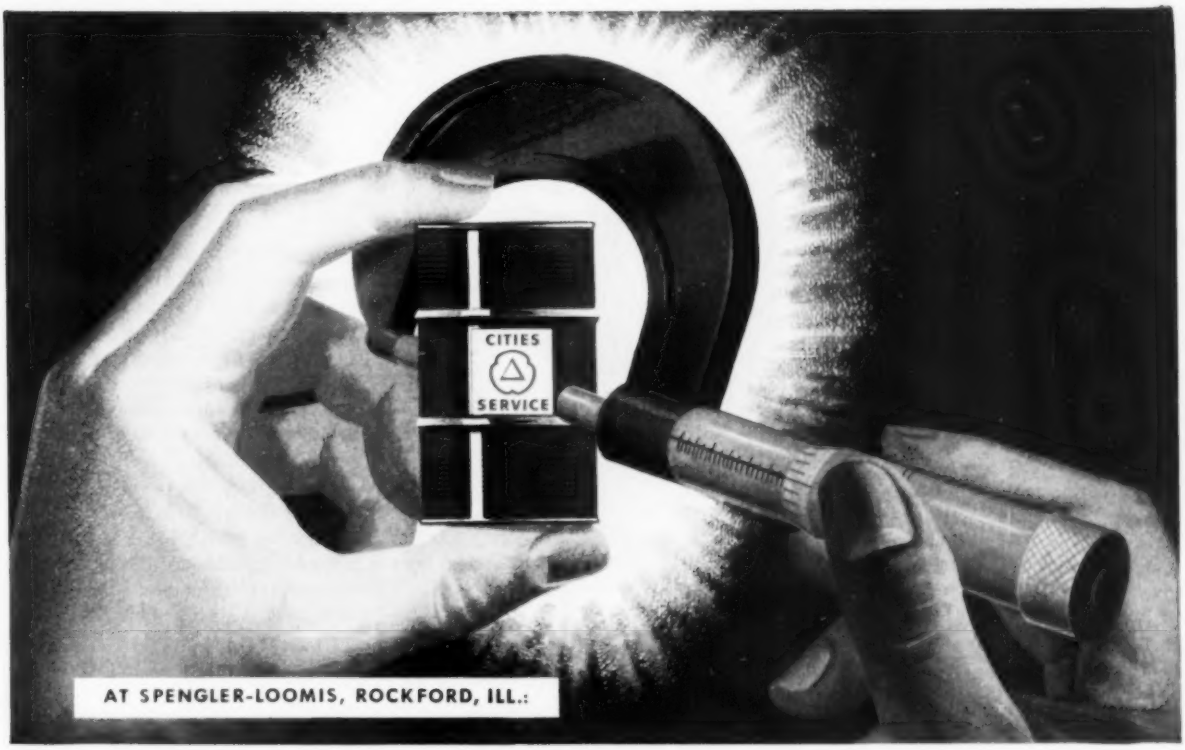
By comparing the influence of other alloy additions, it was concluded that the effect of the boron addition in this steel is approximately equal to an addition of 0.25% Cr.

The mechanical properties of the heat treated 37MnSi5 steel were determined using rod specimens of 35 to 80 mm. (about $1\frac{9}{32}$ and $3\frac{9}{64}$ in.) diameter. The austenitizing temperature was 1560° F. followed by quenching in oil and drawing at 1075 or 1200° F. It was found that, as a general rule, with additions of 4, 8 and 12 lb. of Silcaz per ton of steel, there is a progressive increase in tensile strength with increasing boron content, while the notched-bar impact values behave in the opposite manner.

### BORON IN NICKEL AND MOLYBDENUM ALLOY STEELS

The significance of boron additions to nickel and molybdenum alloy steels is referred to in American literature, and it has been illustrated that with these steels considerable savings, especially in nickel, can be obtained. In order to check these findings a chromium-nickel case hardening steel (No. 1 – 0.014 C, 0.22 Si, 0.51 Mn, 1.12 Cr, 0.66% Ni) and two chromium-nickel-molybdenum heat treating steels (No. 2 – 0.36 C, 0.36 Si, 0.69 Mn, 0.90 Cr,

*(Continued on p. 140)*

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**CUTTER MEASURED WITH MICROMETER.** As a final test, Automatic Pencil Sharpener measures each cutter with a micrometer. All tests proved that Cities Service cutting oil was absolutely tops for this really tough job.

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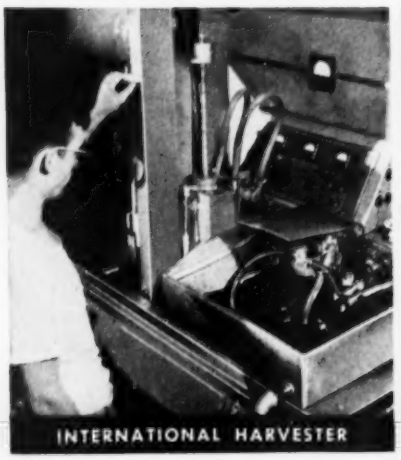

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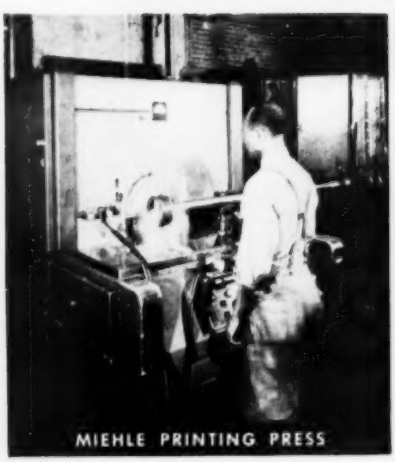

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J-02255


## Boron in Structural Steels

*(Continued from p. 138)*

0.60 Ni, 0.13% Mo; No. 3 – 0.35 C, 0.34 Si, 0.50 Mn, 1.37 Cr, 0.62 Ni, 0.20% Mo) were investigated.

It was found that a slight but definite improvement in the hardenability of steel No. 1 is obtained. On the basis of American results, a very considerable improvement was expected; however, this may be due to insufficient boron additions for this low carbon steel.

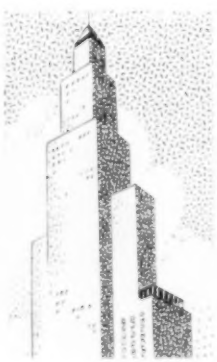
Hardness tests on the boron-free and boron-containing samples do not show any really significant effect due to the boron. However, tensile tests on hardened rods of 30 and 90 mm. (about $1\frac{3}{16}$ and $3\frac{3}{64}$ in.) diameter do show higher ultimate tensile strengths and yield for the boron alloyed steel.

Results are also given for end-quench tests on steels 2 and 3. The authors again find an improvement in hardenability with austenitizing temperatures of 1615 and 1670° F. due to the boron addition. It is concluded that the effect of the boron addition is the same as adding 0.3% chromium or manganese.

On comparing the microstructures of the end-quenched bars, much greater differences in structure were found than could be expected on the basis of the hardness values. In the boron-free steel the precipitation of ferrite is much more rapid than in the boron steel; however, the austenite-pearlite transformation appeared to proceed at the same rate in both.

The mechanical properties of steels 2 and 3 with and without boron were investigated by means of 90-mm. ($3\frac{3}{64}$-in.) bars. The main conclusion reached is that in these steels the impact values are increased by boron additions, whereas in the 37MnSi5 they were decreased.

R. C. Shnay



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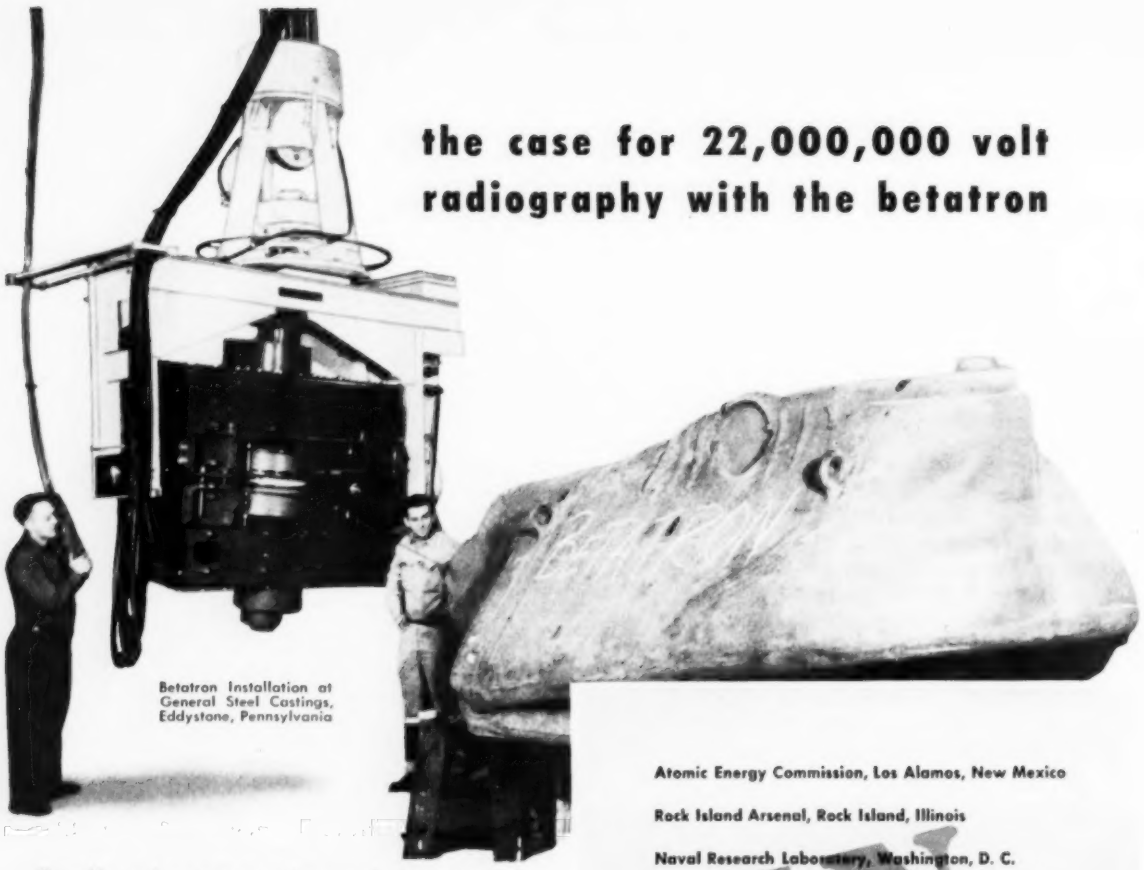

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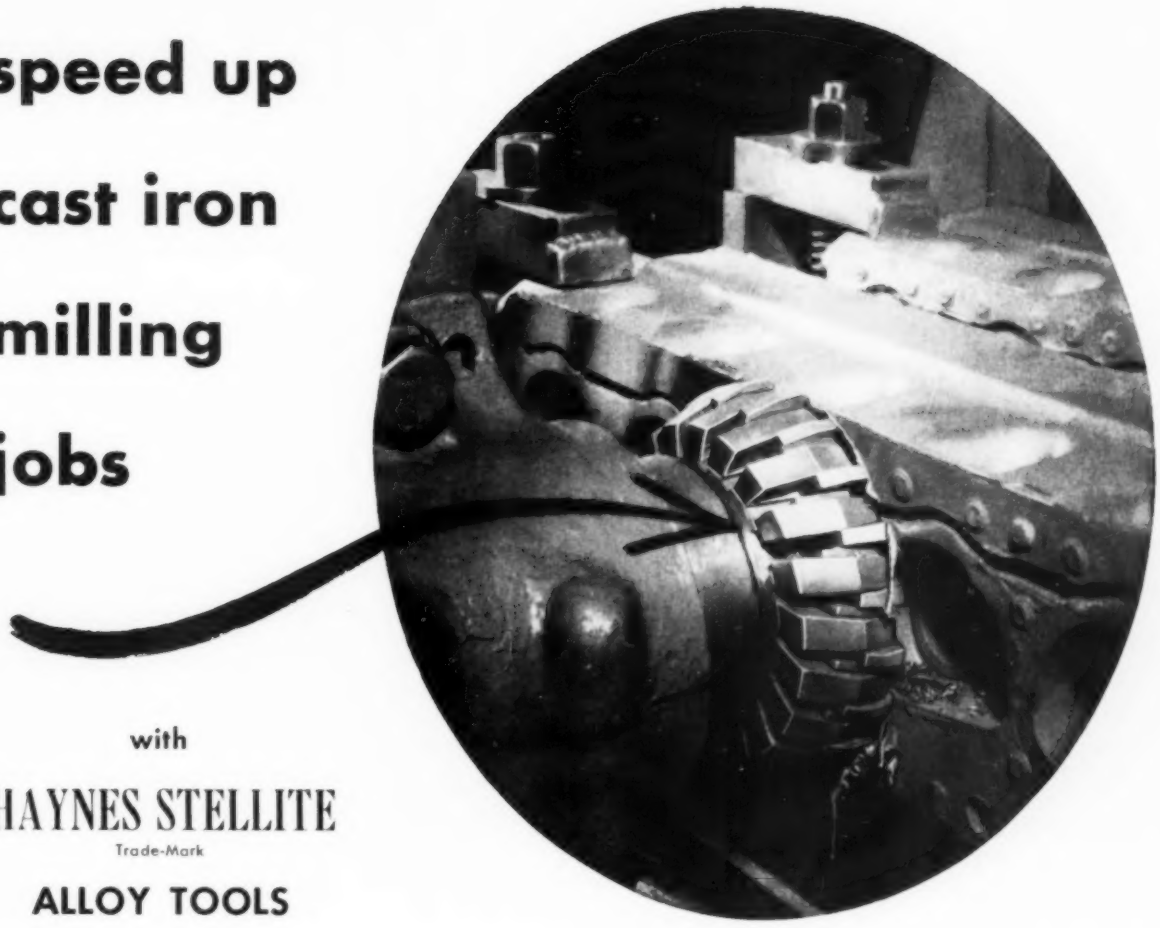

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High compressive strength at cutting temperatures . . . good impact strength . . . and extremely low frictional coefficients make HAYNES STELLITE alloys ideal tool materials for cast iron milling jobs.

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# Tool Steel Topics

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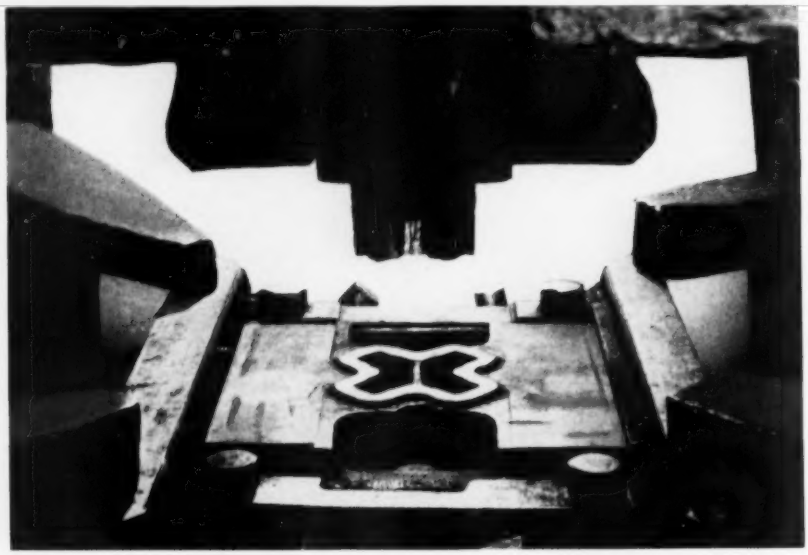


In the center is the four-piece, composite trimmer die used in one of the service tests on Lehigh H tool steel. In the cold-trimming of 20,000 drop forgings, the two die components hardened by the high-temperature, "short-cut" method showed only one-half as much wear as the other two die components heat-treated in the usual way.

## "SHORT-CUT" Hardening Improves Wear of High-Carbon, High-Chrome Steels

Production men often lose patience, even tear out their hair, while waiting the many long hours necessary for the heat-treatment of tools and dies made from the high-carbon, high-chromium tool steels. When treating large dies, for example, it's not unusual to have a pack-hardening cycle of 24 hours or even longer. But until lately there's been no short-cut that doesn't result in improperly treated tools.

### Faster Treatment

That's why we're happy to report that our research men are developing a much faster method of heat-treatment — one that not only promises to save valuable time, but also imparts better wear-resistance than the usual heat-treatment for high-carbon, high-chromium steels.

It's a high-temperature treatment that does the trick. Ordinarily these grades are hardened by a long soak at 1850 F, followed by air-quenching. The new treatment involves a much shorter soak at about 2100 F. By no means perfected as yet, this new wrinkle was developed in a series of experiments in which the dies hardened at 2100 F were used in actual production work along with similar dies hardened at 1850 F.

### Longer Wear

Dies used for cold-trimming drop forgings, for example, were hardened by both methods. These were composite dies, each made up of four assembled sections. Operating conditions were exactly the same. Careful measurements were made at regular intervals to determine the amount of wear between the cutting edges opposite each other. After trimming 20,000 forgings, the wear of the die edges was .012 in. on the pair of trimmer-die components treated by conventional methods; on the dies hardened by the high-temperature cycle the wear amounted to only .006 in. — just half as much.

### Data Now Available

Tests are continuing. If you'd like to have the details of our work to date, drop us a line at Bethlehem, Pa. Address your request to Room 1037A, Publications Department, Bethlehem Steel Co.

## BETHLEHEM TOOL STEEL ENGINEER SAYS:

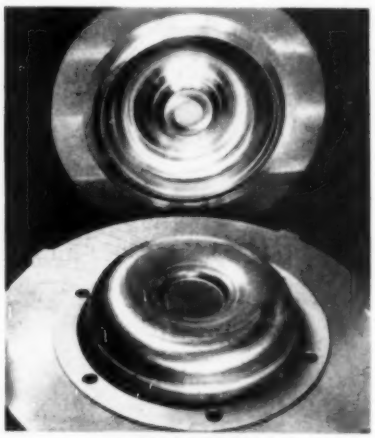
*Here are five fundamentals of successful toolmaking.*

It's always a challenge for toolmakers to produce tools or dies which will be both hard enough to stand up in service and ductile enough not to crack, either in the making or in use. To get the necessary ductility, most tools are hardened below the maximum obtainable.

Once the proper balance between hardness and ductility has been determined in service, the maintenance of this balance helps to assure good performance. But good tool performance depends on more than that. In fact, there are these five fundamentals which must be considered:

1. Good tool design
2. Sound tool steel, of proper grade
3. Correct heat-treatment
4. Proper grinding
5. Proper application of the tool

These five fundamentals are like links in a chain: a deficiency in any one of these steps, or links, can lead to trouble. Poor tool design, for example, may often result in quenching cracks. Careful attention paid to each of these factors will help you to get the best tool life.



**RESTRIKE DIE**

This restrike die made of A-H5 tool steel is one of the precision tools used in making parts for torque converters. A-H5 has better wear-resistance than standard oil-hardening steel and holds more accurately to size during heat-treatment. It's a general-purpose, air-hardening grade containing 5 pct chromium, yet it's as economical as most oil-hardening tool steels.

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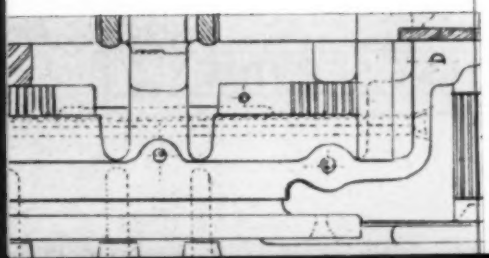

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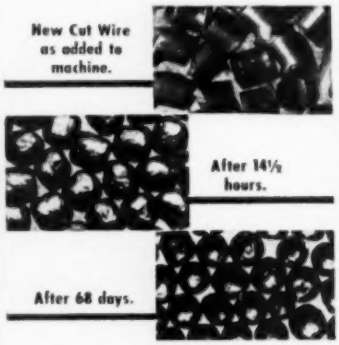


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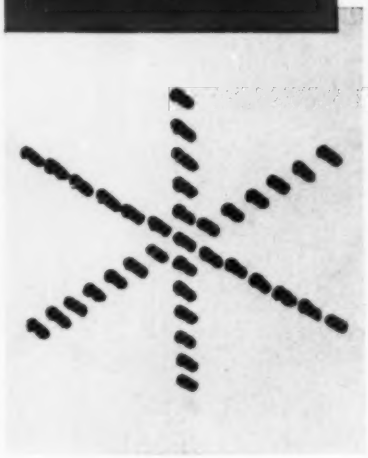
*the permanent abrasive*



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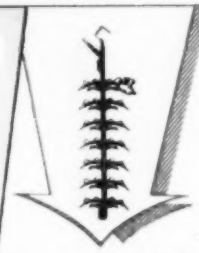

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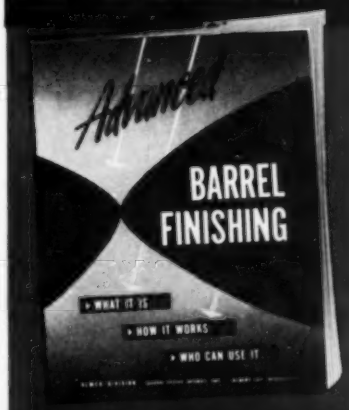


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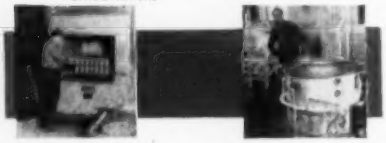

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of any size and shape — any ductile metal

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WIRE PRODUCTS SINCE - 1880


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# Expand Your Plant Potential

WITH *Cooley* ELECTRIC HEAT TREATING FURNACES

fast . . . inexpensive way to expand your plant facilities. Choose from 27 Models.

**For Instance:**

1. You save time and money by keeping heat treat jobs for small parts in plant.
2. It's easy to establish a new department at small cost in proportion to benefits which result.
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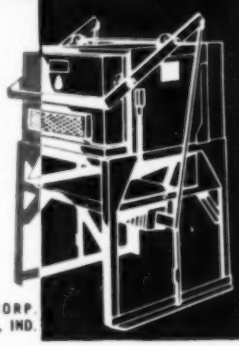

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*Since 1930*

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- Thermocouples
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the most advanced
Salt Bath **Furnaces**
FOR . . . .

***BATCH TYPE WORK***

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# YOU Name it... WE'LL Supply it!

We make containers and fixtures of all types—
for handling parts in heat treating, quenching,
pickling, washing and anodizing operations.
If what you need isn't shown in our catalog,
we'll design and build it for you.

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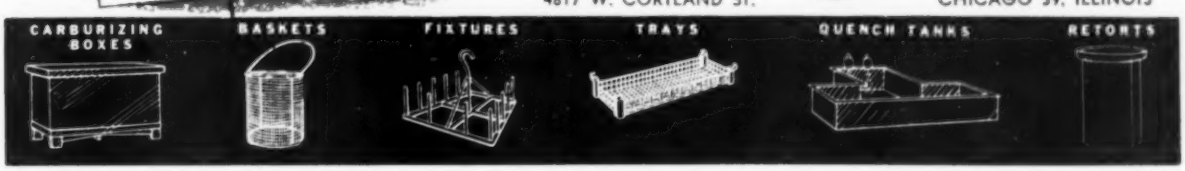


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**measures:**
1. **air flow** 2. **gas flow**
3. **or air flow–gas flow ratio**

Diaflow measurement in open hearth, soaking pit, billet, slab heating and annealing furnace indicates excessive amounts of air and/or gas... helps to prevent fuel and gas waste... serves as a guide in maintaining product quality.

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A complete summary of Hays products applicable to processes such as annealing, brazing and calorizing. Scope includes various methods of firing (underfired, overfired, sidefired), fuel burned (gas, coal, oil), and type of furnace (continuous, rotary hearth, slab heating, etc.).

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*for*
*Every Heat Treating Process*

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**CONTROLLED ATMOSPHERES**

★

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**INDUSTRIAL HEATING EQUIPMENT**

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- Originators and pioneers of ELECTRODE FURNACES including these patented features:
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  2. Starter Coil
- Salts for all heat treating applications (300 to 2300 F.°) supplied by the CROWN CHEMICAL DIV.

**THE BELLIS CO.**
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**October 19 to 23**

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## INDUSTRIAL FUEL BURNING EQUIPMENT..

*Designed* FOR YOUR SPECIFIC REQUIREMENTS

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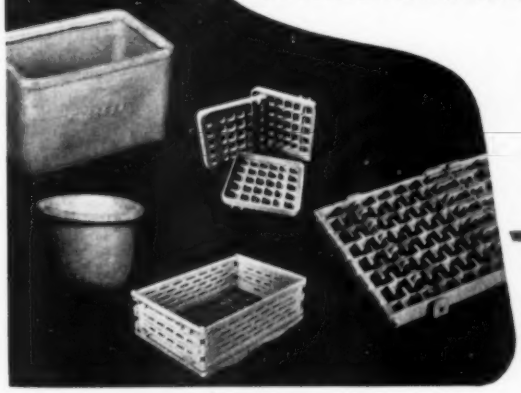

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ENGINEERS FOUNDERS FABRICATORS METALLURGISTS

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**Annealing • Hardening**

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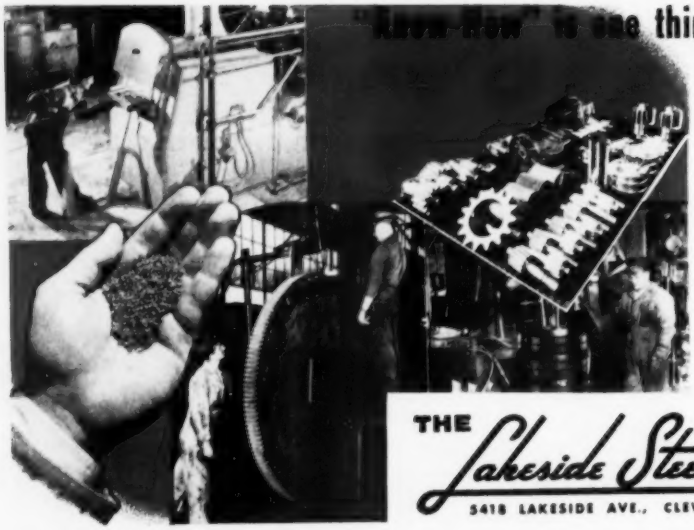

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**HEAT TREATER**

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(for surface hardening stainless steels)

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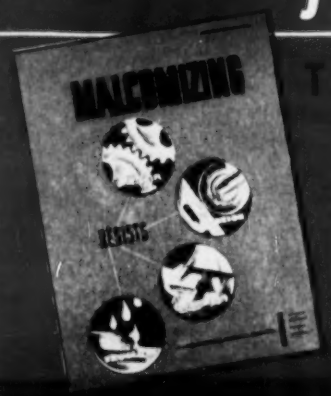


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COMBUSTION UNITS

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Tube Types — 2000-5000° F.
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BODER SCIENTIFIC COMPANY

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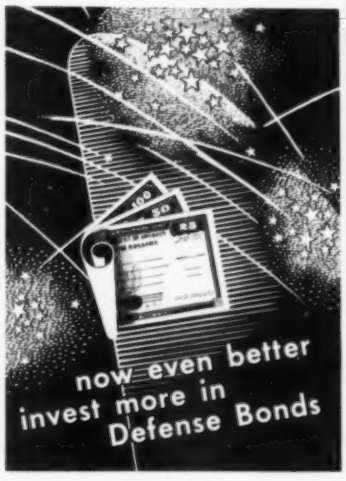


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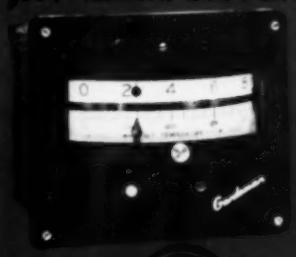
for Precision and Reliability in Temperature Control



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for rapid, accurate, non-destructive
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and FLAW DETECTION from one side

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Ranges: 0.020" to 4", and 0.060" to 12".

**AUDIGAGE** Ultrasonic Micrometer
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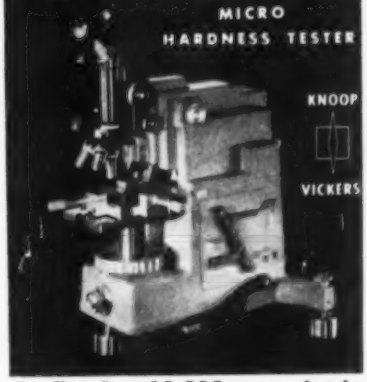
MICRO HARDNESS TESTER




Applies 1 to 10,000 gram loads

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USE OUR
**HOEGANAES SPONGE IRON POWDER**
*for*
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*and other*
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## Solve FLAW DETECTION PROBLEMS with

**FOERSTER PROBOTESTER**

Electronic equipment for non-destructive inspection of *irregularly* shaped iron and steel parts for certain flaws.

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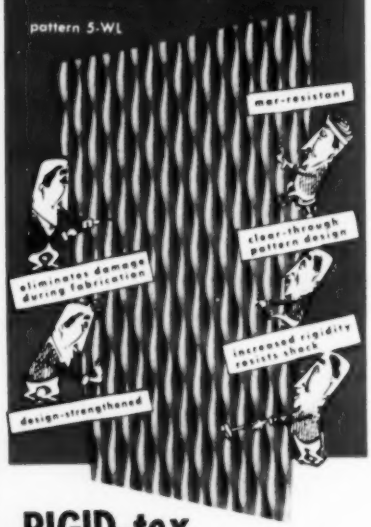


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U-TYPE • WELL TYPE • DUAL TUBE

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U-TYPE MANOMETER

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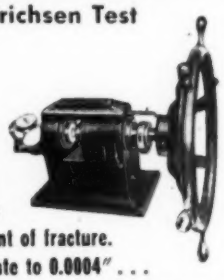
Alexander
**SHEET METAL TESTER**
For Erichsen Test



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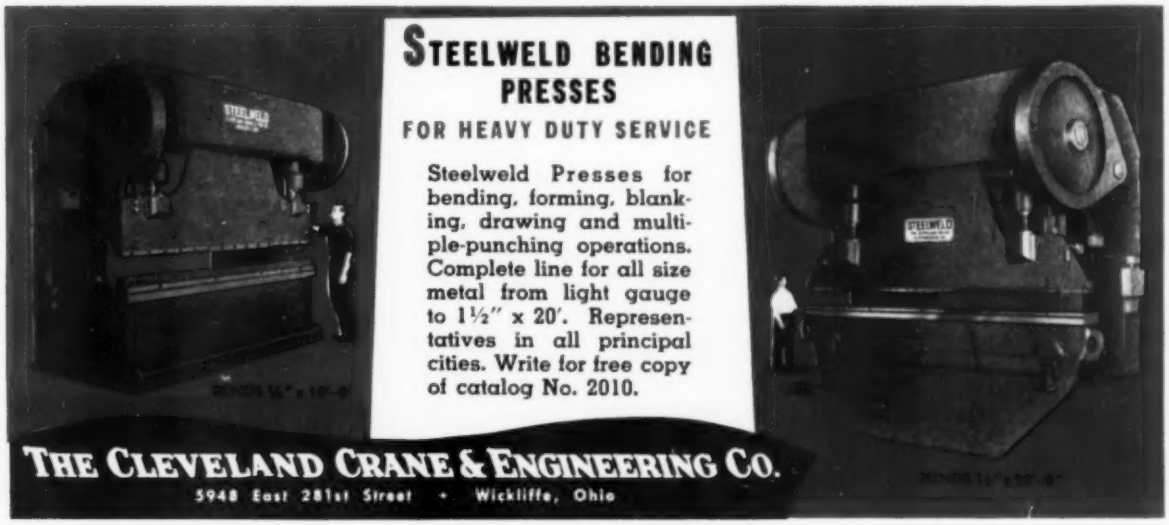
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FOR HEAVY DUTY SERVICE
Steelweld Presses for bending, forming, blanking, drawing and multiple-punching operations. Complete line for all size metal from light gauge to 1½" x 20'. Representatives in all principal cities. Write for free copy of catalog No. 2010.
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*IF SO . . .*

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- ALUMINUM
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The only chemically processed precision spooled electrode wire designed and suitable for ALL TYPES—ALL MAKES inert gas welding equipment.

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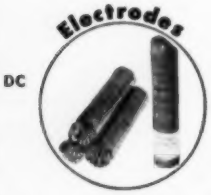


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For degasifying and purifying aluminum alloys. Assures uniformly sound, dense grained castings. Used in reverberatory and crucible type furnaces.

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Specially compounded for die casting aluminum-base metal and permanent mold castings.

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Used for removing magnesium from aluminum alloys

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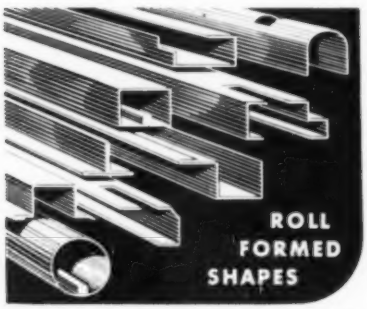


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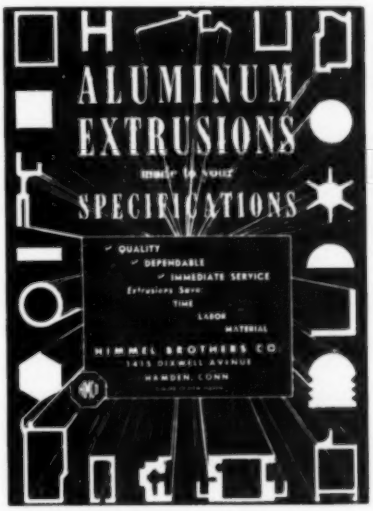


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Regardless of what your joining and silver brazing operations are it will pay you to consider *L-M Silver Brazing Preforms.*
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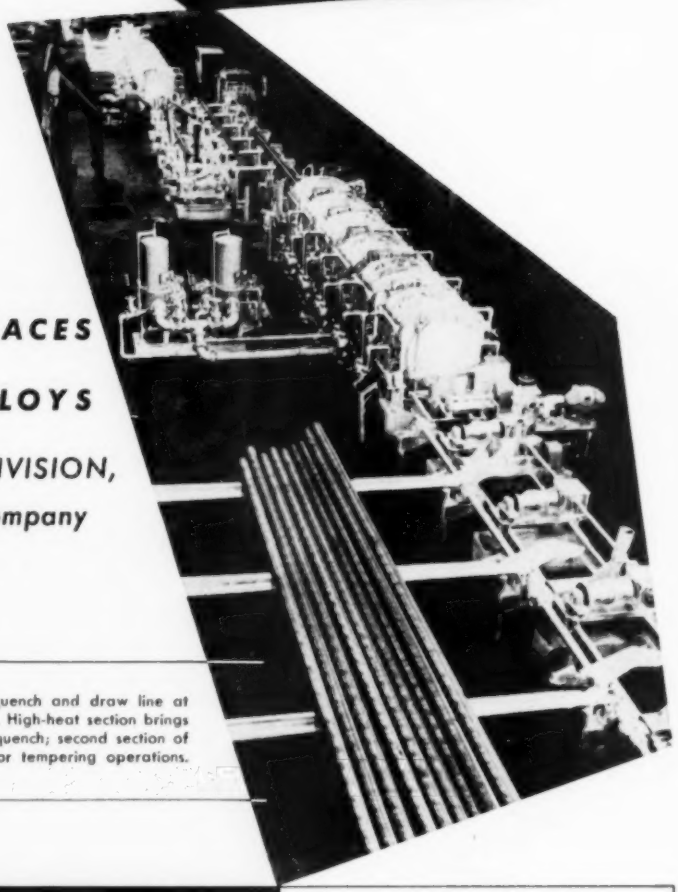
GAS... THE MODERN FUEL FOR ALL INDUSTRY

# GAS FIRED FURNACES CONSERVE CRITICAL ALLOYS

## at SPANG-CHALFANT DIVISION, The National Supply Company



Continuous Gas-fired heat-treating quench and draw line at Spang-Chalfant plant, Ambridge, Pa. High-heat section brings tubing to temperature required for quench; second section of Gas-fired furnaces performs draw, or tempering operations.

- *In production of more than 80,000 tons of deep oil-well casing, critical alloys have been saved as follows:*
- *over 300,000 pounds molybdenum*
- *almost 1,500,000 pounds manganese*

| PHYSICAL PROPERTIES FOR N-80 CASING | |
|---|---|
| MINIMUM YIELD STRENGTH | 80,000 PSI. |
| MINIMUM ULT. TENSILE ST. | 100,000 PSI. |
| MINIMUM ELONG. IN 2" | 16% |

| ANALYSIS OF STEEL BEING USED | |
|---|---|
| CARBON | 0.30 TO 0.40 |
| MANGANESE | 0.60 TO 0.90 |
| PHOSPHOROUS | 0.04 MAX |
| SULFUR | 0.05 MAX |
| SILICON | 0.25 MAX |

For five years, plain carbon steel has been used at Spang-Chalfant Division of The National Supply Co. to make deep oil-well casing, grade N-80. Usually this casing is made with normalized-and-drawn high Mn-Moly steel. This new process gives the necessary characteristics to the casing by means of continuous Gas-fired heat-treating quench and draw line.

Physical properties of the steel show it to be at least equal to the high Mn-Moly casing formerly made.

The heating units, designed by Selas Corporation of America, are composed of twelve radiant Gas-fired furnaces, divided into two sections of six furnaces each. First section brings pipe to quenching temperature of about 1600° F. Second section maintains temperatures of 1050 to 1250° F, depending upon the metallurgical structure of the pipe. Other equipment includes eight carburetors which deliver pre-mixed fuel under pressure to burners, automatic temperature control and recording devices, annular orifice quench head with pumping and filtering equipment.

Two rows of Gas burners on each side of these furnaces permit extremely fast heating. Ceramic burner tips can be replaced while the furnace is operating.

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Zinc plated typewriter key levers are a typical example of how the EBONOL * "Z" process provides an adherent, jet-black inorganic oxide finish to all types of zinc plated surfaces.

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**EBONOL "S"** Processes for blackening steel to produce jet-black oxide coatings. Simple and economical to operate. Operating temperatures: EBONOL "S", 285-290°F., EBONOL "S-30", 295-305°F.

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U. S. PATENT NOS. 2,364,993, 2,460,896, 2,460,898, 2,481,854.

**Write to Enthone, Inc. for information and advice on any blackening process and ask for check list of Enthone literature on over sixty products and processes for better electroplating and metal finishing.**

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# Technical Service Data Sheet

# Subject: HOW *GRANODIZING* PROTECTS STEEL DRUM SURFACES FROM RUST AND IMPROVES PAINT ADHESION

## NEW DEVELOPMENT IN CONTAINER INDUSTRY

United States Steel Products Division, United States Steel Company is now producing grease-free, scale-free, rust-inhibited steel drums. A chemically clean metal surface plus a "Granodine"* non-metallic zinc phosphate coating insures maximum finish durability and underpaint rust-resistance. *Trade Mark Reg. U.S. Pat. Off.

ORDINARY PAINTED DRUM after a year of exposure to weather is badly rusted. Rust was very apparent after only one week.

U. S. S. RUST-INHIBITED DRUM of similar type shows absolutely no rust after same year's test.

## THE PROTECTIVE CHEMICAL TREATMENTS

The Granodizing process embodies the following steps:

1. Grease and dirt removal
2. Full scale removal, after welding the side seam
3. Zinc phosphate coating with "Granodine"
4. Acidulated rinsing in "Deoxylyte" solution

Port Arthur, Texas, Cleaning Line

U. S. S. drums about to enter the 400 foot cleaning and treating line. Powerful impingement sprays directed at the fabricated shell, head, and bottom, insure that the entire interior and exterior of the drum will receive full cleaning and rust-inhibiting treatment.

## ADVANTAGES OF GRANODIZED STEEL DRUMS

These new phosphate-coated steel drums exhibit many advantages for companies using these containers.

They are chemically clean, "water-break free" inside, free of contaminating residues such as grease, oil, drawing and stamping compounds. When the familiar handkerchief test is applied to United States Steel Products' containers processed by their new finishing technique, no contamination of any kind is left on the cloth.

They are free of mill-scale. United States Steel Products is the first steel drum manufacturer to remove harmful mill scale completely ahead of the zinc phosphate coating stage.

They are rust-inhibited with a zinc phosphate-coating. These new steel drums have the added advantage of a non-metallic, paint-bonding "Granodine" zinc phosphate coating. This has been standard practice for many years in the automotive and appliance industries for long-lasting paint protection and metal preservation.

CHEMICALS ACP PROCESSES

**WRITE FOR INFORMATION ON "GRANODINE" AND ON YOUR OWN METAL PROTECTION PROBLEMS**

CHEMICALS ACP PROCESSES

# Vacuum Furnaces for Melting or Processing of Metals

By G. JEWETT CRITES
Manager, Vacuum Furnace Dept.
F. J. Stokes Machine Co., Philadelphia

VACUUM FURNACES are rapidly moving out of the laboratory and assuming commercial importance. For this development, three reasons are of chief importance:

1. They do some things which cannot be done otherwise – for example, the refining of titanium, zirconium and similar active metals.

2. Vacuum furnaces are economical. For 20 years or more they have been used in Europe to avoid the high costs of operating controlled-atmosphere furnaces. Hydrogen, for example, is expensive; it is also hazardous, and the mere physical difficulties of handling bottled gases or the costs of installing gas-generating systems are high.

3. For certain uses of common metals vacuum furnaces can eliminate gas and produce metal of superior quality and performance. Gas has long been known as the enemy of sound metal, the bugaboo of foundry practice. Molten metals with dissolved gases are almost sure to produce unsound castings or ingots. Even if sound, the metal may be embrittled. Magnetic or physical properties of special alloys are impaired. Continuous casting of bronzes and other nonferrous alloys under inert gas has answered the problem for several commercial requirements, but only vacuum melting and casting will serve the purpose when highest purity is demanded.

The success of processing in vacuum rests on the complete elimination of gases from the melt before pouring, without resort to the addition of elements which leave residuals that are equally, but differently, troublesome in character. Vacuum melting and casting reduce harmful gases to a vanishing point or permit their elimination without leaving stable compounds behind. Some trace impurities may also be volatilized and expelled at the prevailing high temperature and low pressure of the vacuum furnace.

Improved characteristics and performance are noted in various ways. For example:

1. Wire can often be drawn to finer size.

2. Alloying elements such as beryllium, chromium, columbium, titanium, and zirconium, because of extreme purity, are effective in smaller quantities.

3. Surfaces of sheet are improved.

4. Conductivity of copper castings and copper wire is greatly improved for electronic applications.

Vacuum distillation and sublimation are also very effective in achieving high purity of numerous metals whose vapor pressure is sufficiently high within the temperature range of the vacuum furnace. Zinc and antimony, for instance, may be removed from lead in this manner. Ancient methods are available for getting rid of most of the unwanted metal and would probably be used except where unusual purity of the refined material were demanded. In such an event, purity of the material going into the vacuum furnace would go hand in hand with reduced operating cost, reclamation of a valuable byproduct, and improved working conditions. Similarly, zinc and lead can

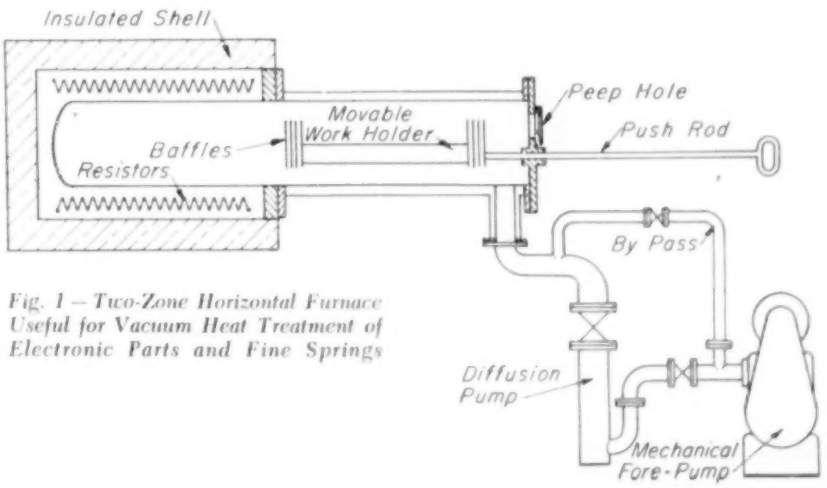



*Fig. 1 – Two-Zone Horizontal Furnace Useful for Vacuum Heat Treatment of Electronic Parts and Fine Springs*

# Vacuum Furnaces

(Starts on p. 161)

be separated from copper in scrap brass; and aluminum and zinc can be separated after being extracted from crude aluminum-silicon alloy by solution in zinc.

At the other end of metal processing is the heat treatment of metals and alloys, such as annealing, bright annealing, sintering and aging. These applications of vacuum processing are less fully developed than melting, refining and casting, but are under continuing study. Even so, exceptionally good results have been observed from bright annealing of sheet and strip in vacuum; surface

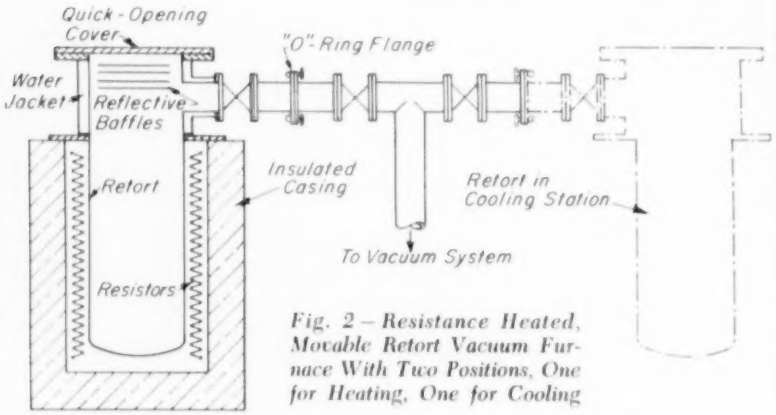



*Fig. 2 – Resistance Heated, Movable Retort Vacuum Furnace With Two Positions, One for Heating, One for Cooling*

condition and fatigue life of certain spring materials have been improved by aging in vacuum. Heat treatment in vacuum is almost essential for titanium and its alloys. It would appear that the mechanical properties of metals which are related to surface conditions are in general responsive to vacuum heat treatment.

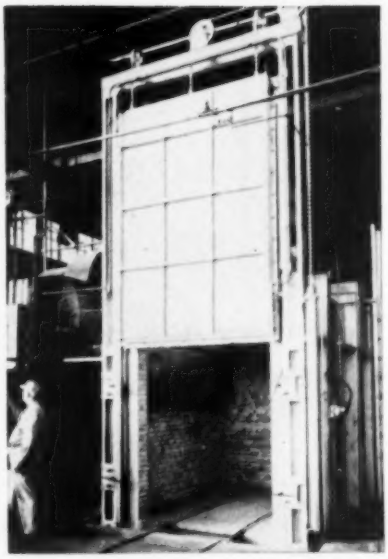
### CLASSIFICATION OF FURNACES

Vacuum furnaces may be generally classified by the type of heating used. The broad classifications are resistance, induction, and arc. Perhaps here is as good a place as any to note that the furnaces under discussion are definitely not laboratory furnaces. They are production units operating in production applications. It is true that at the present time the whole field of vacuum metallurgy could be called in the pilot-plant stage, but at the very least it is safe to say that the vacuum furnaces which are sketched herein are as big as any in the world, and produce hundreds of pounds of metal per batch, rather than ounces or grams.

**Resistance Furnaces** are used for melting materials of low melting point and for degassing and annealing of metals. The temperature limitation of externally heated furnaces is approximately 1850° F. because above this point the existing materials of construction break down. These furnaces have heated resistance elements external to the retort. The chamber containing the elements may be under atmospheric pressure or vacuum – preferably the former. Variations are principally confined to size and arrangement. A typical small horizontal unit for vacuum annealing (Fig. 1) is much used by the timekeeping industry for annealing springs, and by the vacuum-tube industry for annealing tube components. Another uses the vertical-type retorts which are movable and are lowered into the furnace setting (Fig. 2), and others are stationary, with the furnace setting placed around them (Fig. 3). These resistance furnaces are made 6 to 40 in. in diameter and may be up to 50 ft. in length.

It is possible to achieve a temperature of 2750° F., or higher in small resistance furnaces by using a molybdenum or tungsten resistance heater *inside* the vacuum unit. For some high-temperature work this type of furnace is preferred to the corresponding induction unit.

*(Continued on p. 164)*

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**HEAT TREATING FURNACE for CERIUM MAGNESIUM CASTINGS** *at Eclipse-Pioneer Div. of Bendix Aviation Corp., Teterboro, N. J.*

(Patents Applied For)

DIMENSIONS: 6'-0" wide x 7'-0" high x 10'-0" long (clear work space). Also built in other sizes to meet individual requirements.

TEMPERATURE: 300° F. to 1100° F.

ATMOSPHERE: $SO_2$

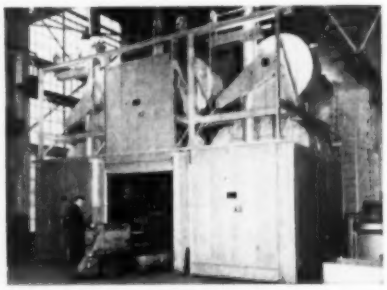
DOOR: Lift type, counterbalanced, with air cylinder for automatic operation.

METHOD OF HANDLING MATERIAL: Steel racks with wheels.

TRACKS: Retractable before door is lowered, to permit tight door seal.

CONSTRUCTION: Heavy steel plate exterior with refractory lining. Air tight.

HEATER: Recirculating-type electric external air heater on furnace roof.



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DUCT SYSTEM: Drop ducts on oven walls assure more uniform temperature control.

WALL CONSTRUCTION: Meyer patented triple slotted insulated steel panels. Patent No. 1843430.

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**Arc Welder, made by Miller Electric Manufacturing Co., Appleton, Wis., uses STRESSPROOF in the generator shaft.**

This 2¼" generator shaft, 19¼" long, must be drilled through its entire length, have both ends stepped down, and keyseated for 10¾". Ground accuracies are required for pressing on the armature. Drilling was a headache and the keyseating often resulted in severe warpage. It required two hours to finish one shaft.

Three different steels were tried before switching over to STRESSPROOF. When Ground and Polished STRESSPROOF was used, machining time was cut in half—one hour instead of two hours. Warpage was eliminated and the shaft itself was much stronger.

STRESSPROOF makes a better part at a lower cost.

STRESSPROOF has improved quality and lowered costs in hundreds of similar applications because of its unique combination of four qualities in-the-bar: (1) High Strength, double that of ordinary cold-finished shafting; (2) Machinability, fully 50% better than heat-treated alloys of the same strength; (3) Wearability, without case hardening; and (4) Minimum Warpage. STRESSPROOF is available in cold-drawn or ground and polished finish.

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# Vacuum Furnaces

*(Starts on p. 161)*

**Induction Furnaces** are chiefly used for melting materials which melt above 1850° F. and for degassing and annealing. In the stationary type (Fig. 4) the induction coil is placed inside the vacuum chamber, and only the charge and the crucible holding it are heated. After the charge is melted, a stopper is pulled from the crucible nozzle, allowing molten metal to run into the mold directly below. Another type is that in which the crucible and induction coil are actually tilted within a stationary chamber while still in vacuum, to pour the melted charge over a lip into a mold placed beside the assembly. Still another tilts the entire mechanism so molten metal runs into a mold suitably attached to the lip. Provision can be made for mechanically stirring the melt and for adding other alloying components after the main body of the metal has been melted.

Vacuum furnaces have been used for the sintering of powder metal compacts. They are usually quite similar to the design sketched in Fig. 4, wherein the space occupied by crucible and mold holds a cylindrical container into which the compacts are stacked.

A modification of the induction furnace is the "magnetic" furnace, which suspends the metal in an electromagnetic field that induces an electric current which heats the metal to its melting point. This unit is not yet fully developed but is under close and continuing study.

**Vacuum Arc Furnaces** are used for melting those metals that have a very high melting point or some characteristic that makes it impossible to melt them in a crucible by either of the above schemes. Zirconium, for example, will combine with the material of any known crucible. Molybdenum, on the other hand, melts

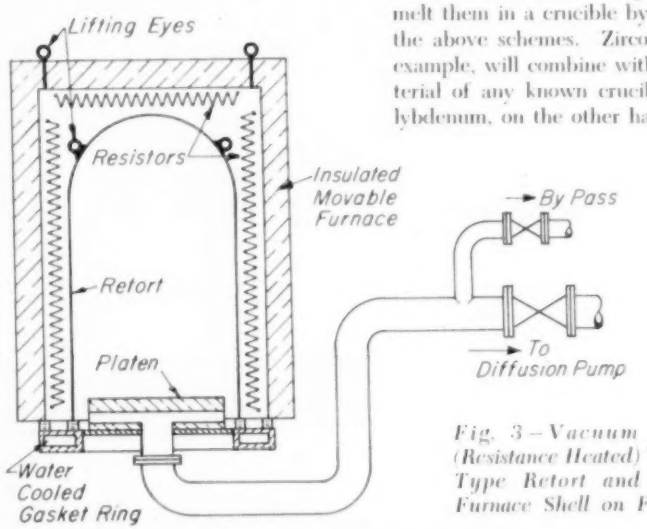


*Fig. 3 – Vacuum Furnace (Resistance Heated) With Bell-Type Retort and Movable Furnace Shell on Fixed Base*

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Custom parts made to your specification or according to description in any technical publication.
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CUSTOM and REPAIR GLASS BLOWING
Do you have expensive glass parts, burets, stopcocks and other items that are not being used because they are broken or cracked? Pack them up now and send them to the LECO GLASS BLOWING SERVICE for repair or part replacement. The cost is small compared with the price of a complete unit. We suggest you tag each item or mark the repair desired on the glass in red pencil and have the shipment insured for an adequate amount. We will be happy to give you an estimate if you wish.
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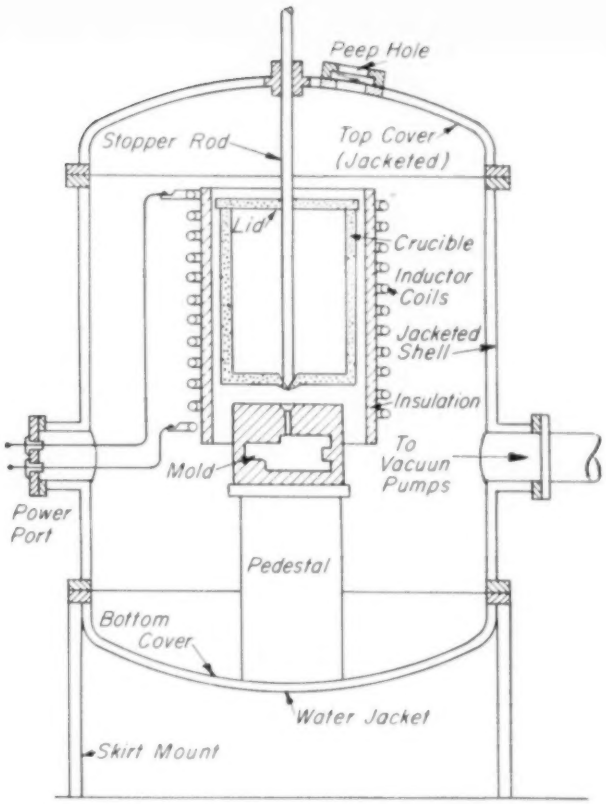
ST. JOSEPH 6, MICHIGAN




at such a high temperature that the crucible would melt first. In the arc furnace an arc is struck between the loose material which forms the ingot being cast and a permanent graphite, molybdenum or tungsten electrode – alternatively, a consumable electrode is made of the metal to be melted. The ingot is usually contained in a water-cooled copper mold. The operation is such that as the molten metal pool grows, the surplus at the boundaries is cooled and solidified by the mold; so doing, it contracts somewhat and does not actually adhere to the sides of the mold. There is always a little molten puddle in the center to take care of solidification shrinkage so that a sound ingot without pipe results.

It is almost a certainty that consumable electrode furnace melting is the ideal method for reactive metals. With consumable electrodes the fusion rate can be accurately controlled. Accurate alloying techniques assure homogeneous ingots.

**Prospective Developments** – At the present time a great deal of work is being done on a

*(Continued on p. 166)*

*Fig. 4 – Stokes Stationary Induction Furnace for Melting and Casting Either Ingots or Complicated Shapes. Top cover has parts for pyrometer and (if necessary) devices for adding alloys*

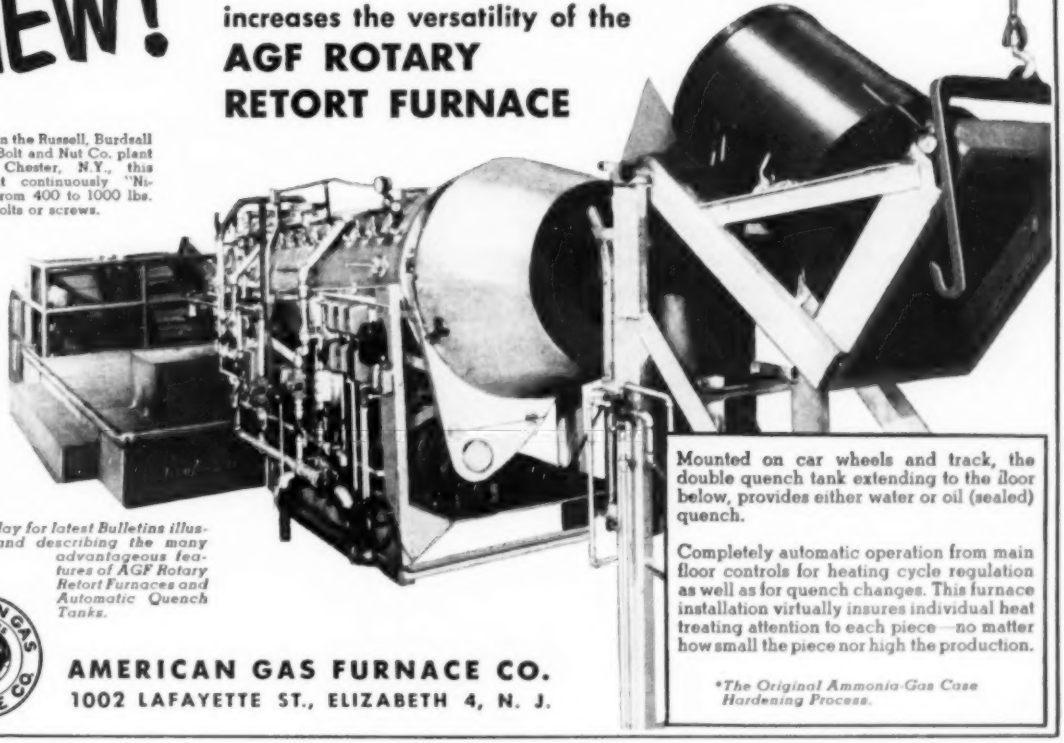

NEW!

**Oil or Water Combination Quench Tank**

increases the versatility of the

**AGF ROTARY RETORT FURNACE**

Installed in the Russell, Burdsall & Ward, Bolt and Nut Co. plant in Port Chester, N.Y., this equipment continuously "Ni-Carbs"* from 400 to 1000 lbs. of nuts, bolts or screws.



Mounted on car wheels and track, the double quench tank extending to the floor below, provides either water or oil (sealed) quench.

Completely automatic operation from main floor controls for heating cycle regulation as well as for quench changes. This furnace installation virtually insures individual heat treating attention to each piece—no matter how small the piece nor high the production.

**The Original Ammonia-Gas Case Hardening Process.*

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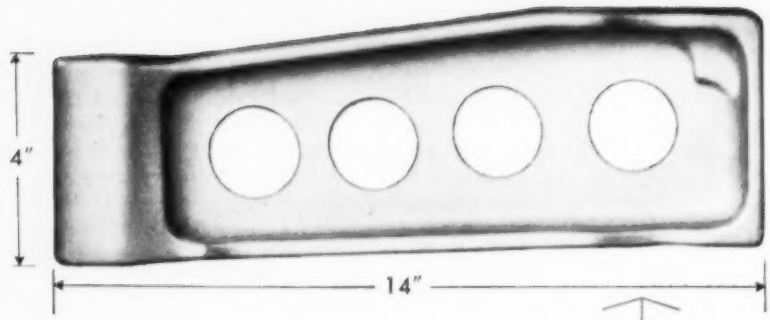


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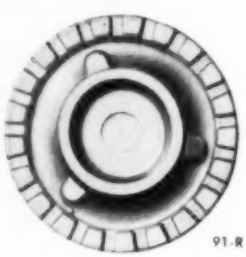
Aluminum Forgings Save Weight, Save Finishing Time and Provide the Same Strength as Steel

If weight and strength are important factors in your product, then Mueller Brass Co. forged aluminum parts may be your best bet. Mueller aluminum forgings weigh only ⅓ as much as steel, yet they are approximately as strong. They make ideal parts for many applications and they are particularly desirable as parts for high speed rotating and oscillating machines because they reduce vibration and bearing loads, thus causing less wear on other parts. They possess good dimensional stability and retain their mechanical properties at high speeds and reasonable temperatures. The smooth, bright surfaces save machining time and eliminate costly finishing. Mueller Brass Co. can forge aluminum parts to your specifications in any practical size and shape from any of the standard or special alloys. Write us today for complete information.



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PORT HURON 20, MICHIGAN

91-R

## Vacuum Furnaces

*(Starts on p. 161)*

laboratory scale in vacuum metallurgy. Some of this work has led to actual process installations, such as the widely known Kroll process for titanium and zirconium.

In the Kroll process for titanium as practiced by the U. S. Bureau of Mines, the ores, usually obtained from Australia or the United States, are purified by chemical methods to the oxide. The purified oxide is mixed with carbon and chlorinated to tetrachloride.

The tetrachloride is introduced into a furnace containing a pot of pure magnesium metal. The furnace is then purged with helium by pulling a vacuum on it two or three times and then breaking the vacuum with helium. When the purge has been completed, the heating elements at the bottom of the furnace opposite the pot of magnesium are energized to melt the magnesium. After this is melted, heating elements opposite the pot of tetrachloride vaporize the tetrachloride; the vapor sinks to the bottom of the furnace and reacts with the molten magnesium to produce the pure titanium plus magnesium chloride. The metal accumulates under the surface of the molten magnesium and magnesium chloride.

The basket of "sponge" so produced in the furnace is removed and placed in a distillation furnace, upside-down at the top of the furnace. A vacuum of approximately 1/10 micron is pulled on the furnace and the top is heated to 1825° F. (1000° C.). This causes the magnesium chloride to melt and run to the bottom of the container where cooling surfaces solidify the chloride and excess magnesium. After the greater part of the contaminant has melted and run off, the rest vaporizes and is condensed on cool surfaces below. The final product is quite pure metal.

Modifications of the Kroll process used in the production of zirconium are described on p. 99. The F. J. Stokes Machine Co. has installed complete equipment for the Kroll process, including the furnace, the furnace settings, the pumping system, and minor components. At the present time, the engineering techniques of manufacture and use must usually be contributed by the equipment maker.

## Ultra High-Strength Steels

*(Continued from p. 96)*

Sizable savings in weight lend attraction to aircraft designers, and the industry should take advantage of this saving.

4. What precautions are needed?

*(a)* Stress concentrations must be avoided.

*(b)* Embrittlement after plating must be avoided or entirely relieved.

*(c)* Points of attachment should be carefully designed and abrupt changes in section avoided by providing self-aligning members.

Suggested mechanical property design allowables were:

Ultimate tensile stress, 256,000 psi.
Tensile yield stress, 192,000 psi.
Ultimate shear stress, 148,000 psi.
Elongation, 11.0% in 2 in.
Izod impact value, 14 ft-lb.

The proposed Izod impact value appeared to be rather low, in the view of some commentators.

However, the standard fatigue and impact specimens are freely acknowledged to be inadequate in reflecting operational conditions endured by aircraft components. This circumstance has increased costs considerably, since many additional parts must be manufactured for dynamic and sustained load testing.

Many failures have occurred in airplanes at rest, where parts under sustained loads had not been properly manufactured. These failures emphasize the fact that design must be based upon operational load life; manufacturing and processing controls must also be changed to eliminate errors in fabrication.

An invitation was extended to metallurgists to find more efficient methods of neutralizing residual stresses and minor flaws in commercial materials. Much more desirable would be steels of better quality. The aircraft industry would expect to pay more for such materials.

The consensus seemed to be that the outlook for ultra high-strength steels in aircraft is bright, since experience with less ductile aluminum alloys has proven generally satisfactory. Designers will see to it that ultra high-strength steels become airborne and will be looking forward to the Super Ultra Ultra to be spawned in the laboratories of America – perhaps in time for the next Western Metal Congress.


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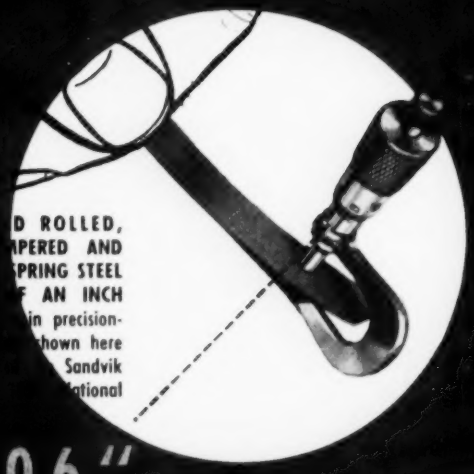

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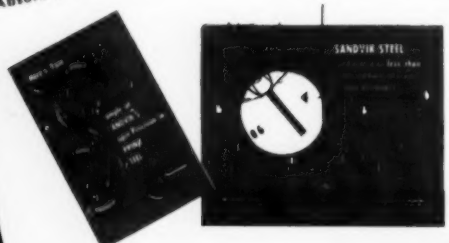


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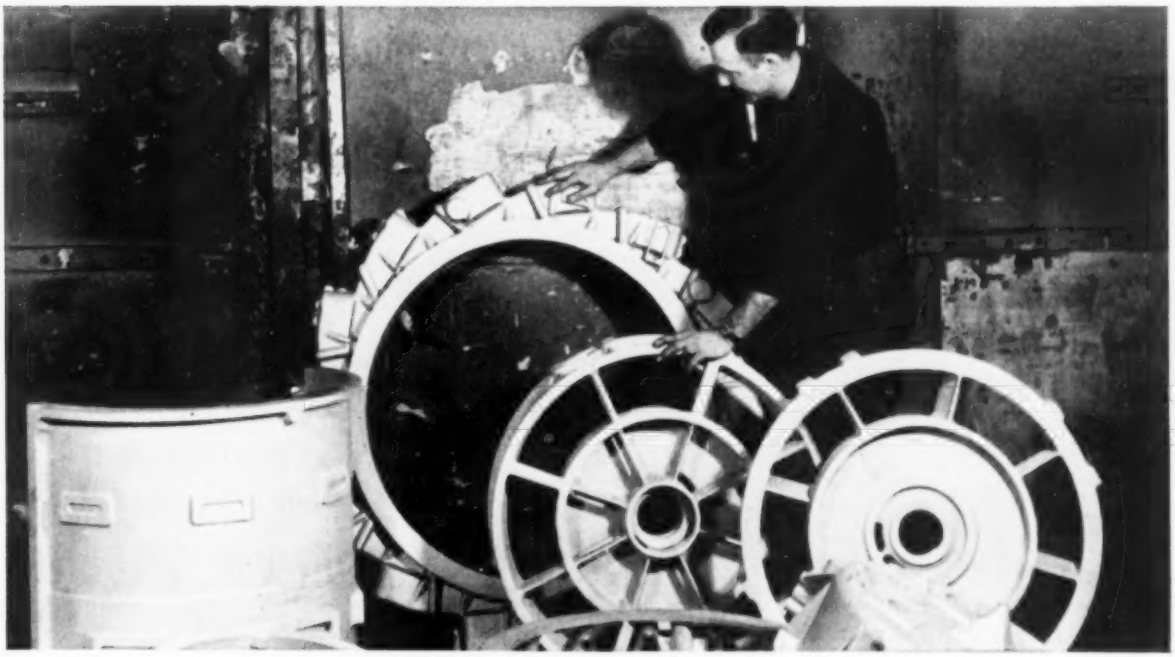

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For further information on the advantages of magnesium, contact your nearest Dow sales office or write THE DOW CHEMICAL COMPANY, *Magnesium Department*, Midland, Michigan.

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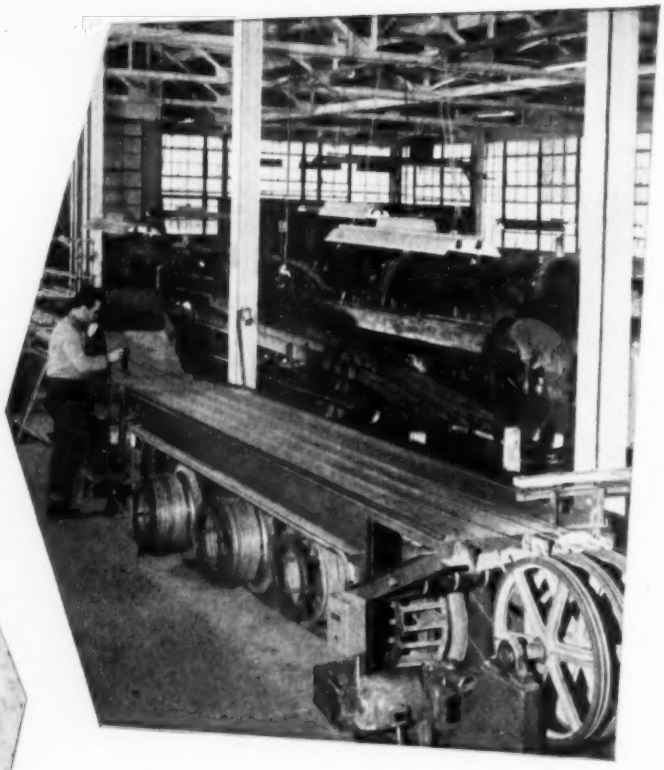
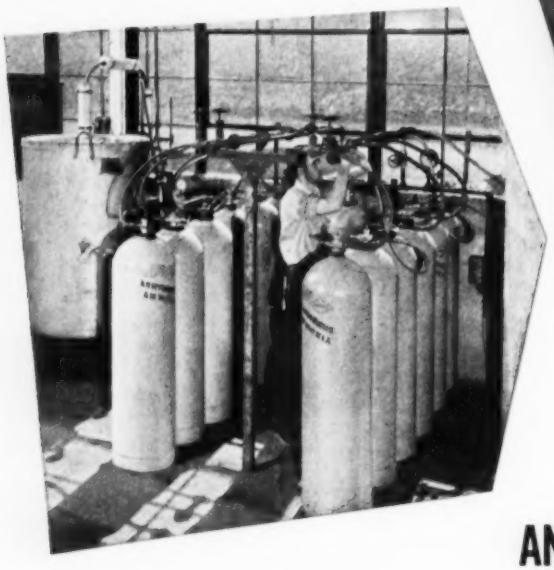


Tubing leaving the annealing furnace through a sand curtain at J. Bishop & Co., Malvern, Pennsylvania



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# Embrittlement of Heat Resisting Steels*

THE AUTHORS have reviewed a number of papers dealing with the embrittlement of steels after heating for extended periods in the vicinity of 930° F. under various conditions of stress. Most of the information is of German and Swiss origin and an attempt has been made to assemble and analyze the most pertinent of the data.

Retained properties of broken bolts were determined at room temperature by several investigators after operation at 930° F. It was found that neither hardness nor unnotched bending tests could reveal the embrittlement, but that significant results could be obtained with notch-impact tests. Cr-Ni-Mo steels embrittled most readily while trouble was seldom encountered with Cr-Mo steels. Given sufficient time (22,000 hr.) at operating temperature, stress was not a prerequisite in the embrittlement of Cr-Ni-Mo steels. Reheat treatment greatly improved the impact properties of these bolts. One investigator, after a survey of bolting failures, reported that the service time necessary for embrittlement varied from 3000 to 12,000 hr., depending on composition and loading.

Various investigations made to determine room-temperature properties after extended heating periods at 930° F. were summarized. Cyclic heating and cyclic stressing were both employed. Stresses were limited to design creep strengths. In these tests also it was pointed out that the embrittlement was not revealed by tension, unnotched bending or hardness, but the notch-bar impact test clearly revealed embrittlement. Results of these tests after 2000 to 3000-hr. exposure showed Cr-Ni steels to be most severely embrittled and Cr-Mo steels least embrittled, with Cr-Ni-Mo steels intermediate. The major portion of the severe embrittlement appeared to be due to heating alone. Cyclic stressing did not embrittle a steel which was unaffected by heating alone. The notched bars indicated (at least in the shorter heating times) that creep damage was great compared to the embrittlement due to heating alone. Steel analyses of the specimens ran approximately 0.30 C, 2.90 Ni, 1 to 1.25 Cr and 0.8 to 1.5 Mo.

The retained impact properties of fractured stress-rupture specimens of five alloys were studied after exposures up to 20,000 hr. Very severe and rapid embrittlement was observed for Armco iron and the Cr-Ni-Mo steels (0.11 C, 0.46 Mn, 0.22 Si, 0.72 Cr, 0.88 Mo, 1.53 Ni), and equally severe but slower embrittlement for the Cr-Mo-V-W steel (0.19 C, 0.34 Mn, 0.36 Si, 2.71 Cr, 0.51 Mo, 0.48 W, 0.74 V). At sufficiently long times to rupture, the impact strength of mild steel (0.22 C, 0.52 Mn, 0.24 Si) and stainless steel (0.10 C, 0.62 Mn, 0.60 Si, 18 Cr, 8.4 Ni, 0.67 Ti) showed recovery. Percentage reduction in impact strength after stress-rupture (creep damage) and percentage reduction in impact strength after reheat treatment of stress-rupture specimens (permanent damage) were compared at various

*(Continued on p. 172)*

*Digest of "A Survey of Embrittlement and Notch Sensitivity of Heat Resisting Steels", by G. Sachs and W. F. Brown, Jr., American Society for Testing Materials Preprint No. 74, 1952.

## REVIEWER'S NOTE

Alloy bolting steels in common use in this country are specified by A.S.M.E. Boiler Code per A.S.T.M. Standards. For temperatures from 900 to 1100° F. the following steels are listed:

| A.S.T.M. Spec. | Grade | Alloy Type |
|---|---|---|
| A-193 | B-5 | 4 to 6% Cr + Mo |
| A-193 | B-7 | A.I.S.I. 4140 to 4145 |
| A-193 | B-7a | A.I.S.I. 4140 to 4145 (0.5 to 0.7% Mo) |
| A-193 | B-14 | 0.80 to 1.15% Cr, 0.3 to 0.4% Mo, 0.2 to 0.3% V |
| A-193 | B-16 | 0.80 to 1.15% Cr, 0.45 to 0.65% Mo, 0.25 to 0.35% V |

While A.S.T.M. Spec. A-193, Grade B-4, lists a Cr-Ni-Mo steel of approximately A.I.S.I. 4340 composition for high-temperature service, the A.S.M.E. Code for Unfired Pressure Vessels does not list this steel, indicating recognition of the effect of nickel in these alloys under service conditions of high temperature and stress.

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## Embrittlement of Heat Resisting Steels

*(Continued from p. 171)*

stress levels for the Cr-Ni-Mo and the stainless steels. The observation was made, among others, that permanent damage develops progressively at any stress for the Cr-Ni-Mo steel, while permanent damage of the stainless steel does not become great until a relatively large fraction of its total life is exhausted. It also appears that for the Cr-Ni-Mo steel, creep damage is independent of stress while permanent damage shows dependence on the stress level.

### INFLUENCE OF NOTCHES

Investigations conducted primarily in Germany and Switzerland on Cr-Ni-Mo steel lead to the conclusions that a notch may either strengthen or weaken the steel, and that creep-damage and notch-sensitivity are related in low-alloy steels. Recent work at N.A.C.A. involving stress-rupture tests of notched specimens, where a sharp 60° "V" notch removed 60% of the cross-sectional area, indicates that the notch response of the low-alloy steels tested was time and temperature-sensitive, and the temperature range of notch sensitivity depended on the alloy composition. In general, the strength of the notch bar was 50 to 60% of the unnotched specimen in the range of maximum notch sensitivity. The maximum embrittling effect moves progressively to lower temperatures and increases in magnitude as the time to rupture increases.

It is hypothesized that the embrittlement is a precipitation reaction where the increased resistance to grain boundary deformation results in a material very sensitive to stress concentrations, either in the form of external notches or internal flaws. The precipitate is thought to aid in the formation of intercrystalline cracks and to provide a structural condition of low ductility. There appear to be several factors which separately or in conjunction result in the embrittlement observed: temper brittleness which would result in rather rapid embrittlement, long-time heat embrittlement, creep damage and notch-rupture sensitivity. The Cr-Ni-Mo steel was embrittled only slightly when heated up to 9000 hr. at 930° F., but was subject to high creep damage and notch-rupture sensitivity. The addition of nickel in amounts of 0.9 to 1.5% to

*(Continued on p. 174)*

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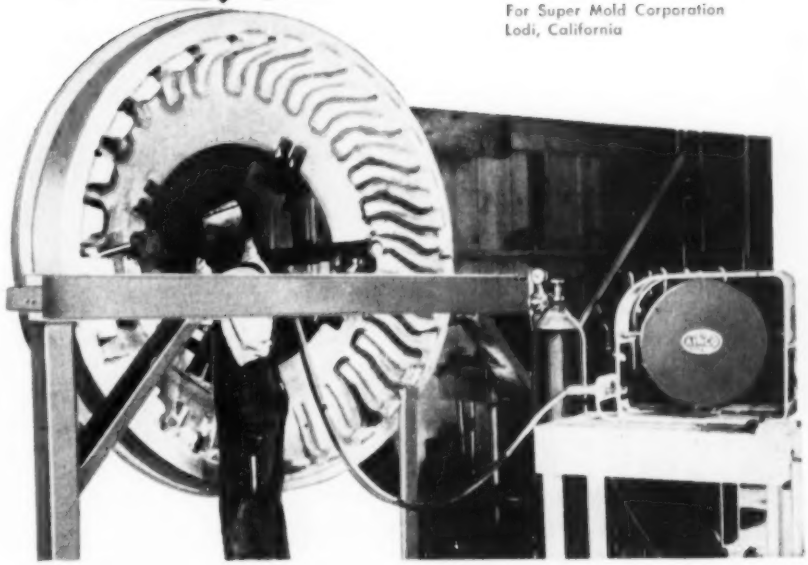

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## Embrittlement of Heat Resisting Steels

*(Continued from p. 172)*

Cr-Mo steels is definitely indicated to be deleterious. It is especially worthy of note that spheroidizing eliminated the notch-rupture sensitivity of the Cr-Ni-Mo steel. The tests at N.A.C.A. indicate that freedom from notch sensitivity, and probably creep damage, at one temperature is no assurance that large effects may not be present at another temperature. In general, heat treatments designed to increase strength appear to increase the tendency toward notch-rupture sensitivity and creep damage. R. A. HUSEBY

## Simplified Metallography for Zirconium*

IT IS GENERALLY agreed, as attested by the available literature, that zirconium is difficult to prepare for microscopic examination, this being due primarily to the marked tendency of the metal to flow or smear during grinding and polishing. An improvement over the conventional metallographic techniques used for this metal resulted when a bright-pickling solution was investigated for its applicability to metallography. A simple technique was evolved by which zirconium and hafnium and their alloys can be prepared for examination in 5 min. by a chemical-etch method without the aid of mechanical or electrolytic polishing. The resulting microscopic structures can be studied equally well under bright-field or polarized lighting.

The acids of the polishing solution work satisfactorily in glycerine, water or hydrogen peroxide. The composition and recommended uses for these are given in the tabulation on p. 178. If one of these three compositions is found to be best suited for a particular specimen but gives results short of those desired, improvements can usually be made either by increasing or decreasing the acid contents.

A specimen for routine grain-size

*Digest of "A Simplified Procedure for the Metallography of Zirconium and Hafnium and Their Alloys", by F. M. Cain, Jr., a paper presented at the Symposium on Zirconium, Los Angeles, March 1953. Work reported in the paper was performed under AEC Contract AT-11-1 Gen-14.

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## Simplified Metallography for Zirconium

*(Continued from p. 174)*

determination need not be mounted and requires only a 180-grit silicon carbide or a good machined finish. However, for a study of detailed structure, a specimen should be mounted in bakelite and abraded through a 300-grit emery or a 600-grit silicon carbide wax-lap finish. It is suggested that pressures of 300 psi. or lower be used to avoid formation of twins from cold work.

The chemical polish of the specimen is obtained by swabbing with, or dipping into, the polishing solution (swabbing is preferable). After a few seconds a brownish-yellow vapor of nitrous oxides evolves from the surface of the specimen, indicating that the polishing action has started. The average specimen requires contact with the acid for only 5 to 10 sec. after the appearance of this vapor. The specimen is then immediately washed in cold running water and dried. This procedure can be repeated if the specimen has not been sufficiently polished. Figure 1 is 25% Sn-Zr alloy polished in solution C.

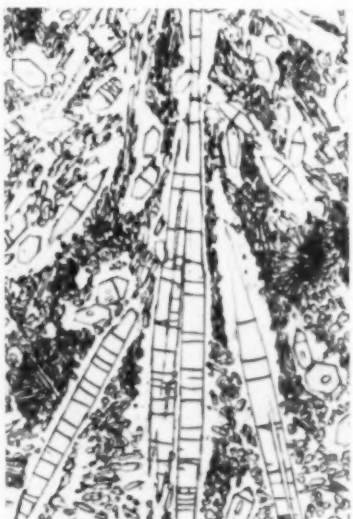
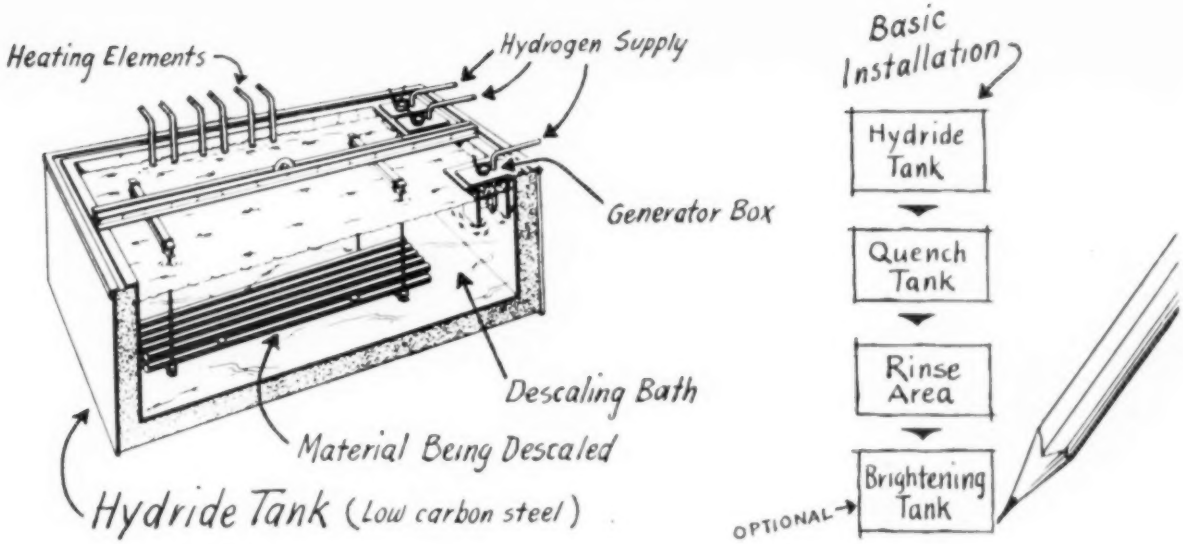


*Fig. 1 — As-Cast 25% Sn-Zr Alloy, Chemically Polished in Solution C. Bright-field illumination, 250×*

A chemically polished specimen can be stained by swabbing it with a solution consisting of 1 part of polishing solution B and 3 to 5 parts of

*(Continued on p. 178)*

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## Simplified Metallography for Zirconium

*Fig. 2 — Zirconium, Chemically Polished in Solution B, Then Heated to 1275° C. (2325° F.) in Vacuum, Quenched in a Jet of Helium. Photographed under polarized light, 1000 ×*

*Fig. 3 — Hafnium, Chemically Polished in Solution B, Then Cycled Between Room Temperature and 1300° C. (2370° F.) in an Argon Atmosphere. Bright-field illumination. 100 ×*

*(Continued from p. 176)*

water. The progress of staining can be observed visually and stopped by washing the specimen in running water. A stained specimen is best examined or photographed with bright-field illumination, but gives effects similar to those of polarized light; it provides contrast between grains for bright-field study when polarized light is not available.

Preparation of specimens for study of surface phenomena occurring during vacuum or controlled atmosphere heating is easily done. Figures 2 and 3 are examples of two such observations.

**Compositions and Uses of Chemical Polishing Solutions**

| Polishing Solution | Composition and Recommended Uses |
|---|---|
| A | 45 ml. $C_2H_5OH$<br>45 ml. $HNO_3$ (conc.)<br>8 to 10 ml. HF (48%)<br>Zirconium and low percentage alloys |
| B | 45 ml. $H_2O$<br>45 ml. $HNO_3$ (conc.)<br>8 to 10 ml. HF (48%)<br>Pure zirconium and high percentage alloys |
| C | 45 ml. $H_2O_2$ (30%)<br>45 ml. $HNO_3$ (conc.)<br>8 to 10 ml. HF (48%)<br>Pure zirconium and high percentage alloys |
| *D | 60 ml. $H_2O_2$ (30%)<br>30 ml. $H_2O$<br>8 to 10 ml. HF (48%)<br>Iodide-titanium |

*By swabbing for 30 to 60 sec.

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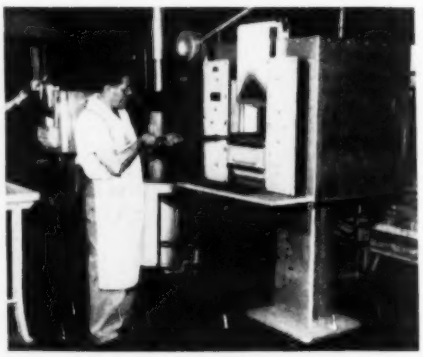

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# Improving Machinability of Casting Surfaces*

HIGH ABRASIVENESS of the "skin" of sand-cast gray iron to cutting tools has long been a matter of concern to metals and production engineers. They have worked in many directions toward alleviating it and thereby extending tool life when machining casting surfaces. Tumbling, shotblasting, pickling (acid and electrolytic), annealing and oxidizing treatments have been tried, with varying degrees of success.

To evaluate precisely the relative surface abrasiveness of castings receiving different pre-treatments, a study has been made of a large number of cast specimens identical in shape and analysis. They were in the form of cylinders with 6-in. o.d., 4-in. i.d. and 18-in. length, having the following analysis: 3.25% total C, 0.56 to 0.78% combined C, 2.28% Si, 0.12% S, 0.25% P, and 0.62% Mn. Tensile strength was 36,000 psi., Brinell hardness 190.

Single-point cutting tools were of the 18-4-1 high-speed steel type, $\frac{3}{8}$ in. square. All cutting was done dry on a 14-in. engine lathe. To duplicate commercial practice as closely as possible, a depth of cut of 0.100 in. and feed of 0.00625 in. were selected. In determining their relative life, tools were run to complete failure by allowing the flank abrasion to develop sufficient heat between the tool and the work to cause breakdown of the point.

Measurement of cutting forces under shop conditions required dynamometers of the same size and shape as the commercial toolholders and of equivalent rigidity to eliminate excessive vibration and chatter. So a two-component electric resistance strain-gage dynamometer was made from an S.A.E. 1040 steel, with four active gages mounted near the top and bottom fiber axes to permit permanent force readings to be made on an oscillograph tape in the range of 0.5 to 1000 lb. Both the cutting force and the feeding force were measured on the castings.

Principal emphasis of the investigation was on tool life or, more exactly, on cutting speed for constant tool life. In one group of 6 test cylinders it was found that the cutting speed for a 20-min. tool life was 105 ft. per min. for the tumbled surface, 173 ft. per min. for the pickled surface and 184 ft. per min. for the interior of the casting. In other words, the interior could be machined 75% faster than the abrasive surface and, after an acid pickle, the machinability of the as-cast surface could be boosted 65%.

For another series of castings, cutting speeds for 20-min. tool life after various annealing and pickling treatments were summarized as follows:

| CONDITION | A | B | C |
|---|---|---|---|
| As-cast surface | 190 | 94 | Base |
| As-cast interior | 190 | 144 | 53.2 |
| Pickled surface* | 187 | 135 | 43.7 |
| Annealed surface | 105 | 160 | 61 |
| Annealed, oxidized interior | 121 | 190 | 102 |
| Annealed interior | 121 | 287 | 208 |
| Annealed, pickled surface | 116 | 310 | 230 |
| Annealed interior | 105 | 390 | 315 |

A = Brinell hardness.
B = Speed, ft. per min.
C = Percentage increase.
*Electrolytic salt bath.

Since annealing of castings prior

(Continued on p. 182)

*Digest of "Relative Abrasiveness of the Cast Surfaces of Various Gray-Iron Castings on Single-Point Tools of High-Speed Steel", by Joseph Datsko and O. W. Boston, *Transactions* of the American Society of Mechanical Engineers, Vol. 75, January 1953, p. 103-108.


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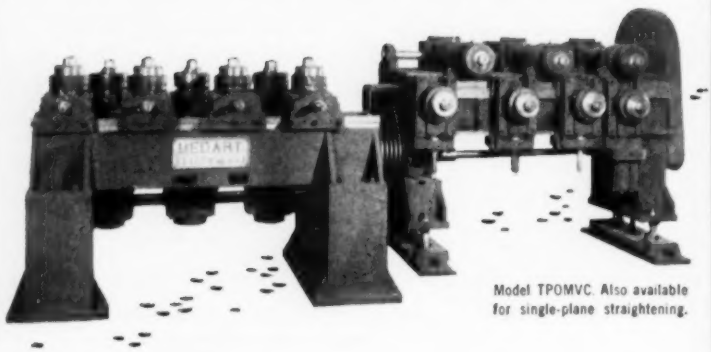

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## Improving Machinability of Casting Surfaces

*(Continued from p. 180)*

to machining is practiced widely, it is interesting to note that this investigation points to the fact that while machinability of the casting is improved by annealing, the skin effect becomes more pronounced because the machinability of the interior is increased to a greater extent (315%) than is that of the surface (61%).

The electrolytic pickling treatment referred to is highly effective in improving machinability of both the as-cast surface and after annealing. A 20-min. pickle of this type, for example, improved machinability 230% over the as-cast condition and 95% (about double) over the annealed, unpickled surface. The explanation is that the pickling operation removes all scale, burned-in sand, sand inclusions and graphite, leaving only clean iron to meet the cutting tool.

From a practical standpoint, it is related that one company has estimated possible savings in tool cost of over $350,000 annually in machining three castings for an engine through the use of electrolytic pickling to reduce abrasiveness of as-cast surfaces.

A. H. ALLEN

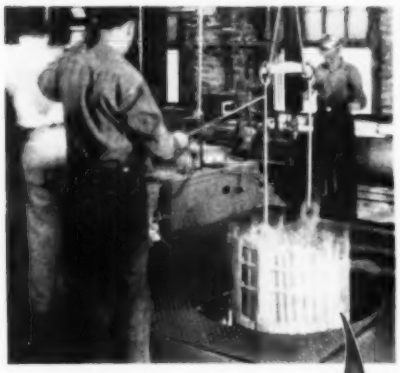
## Recent Microscopical Techniques in Metallurgy*

A GENERAL SURVEY is made of the microscope as used in metallurgy, and the advantages of the more recent techniques are described and, in a number of specialized cases, illustrated by means of photomicrographs. Many minor yet useful techniques had to be omitted for the sake of brevity.

Magnification and resolution are closely related. Factors of total magnification are: Primary magnification of objective, secondary magnification of eyepiece, tertiary magnification by extension of the camera bellows. Total magnification exceeding 1000 times the numerical aperture (N.A.) of objective is an empty magnification, which, when over 2000 N.A.

*(Continued on p. 184)*

*Digest of "Specialized Microscopical Techniques in Metallurgy", by S. Tolansky, Symposium on Properties of Metallic Surfaces, 1952, p. 1-22, published by the Institute of Metals.



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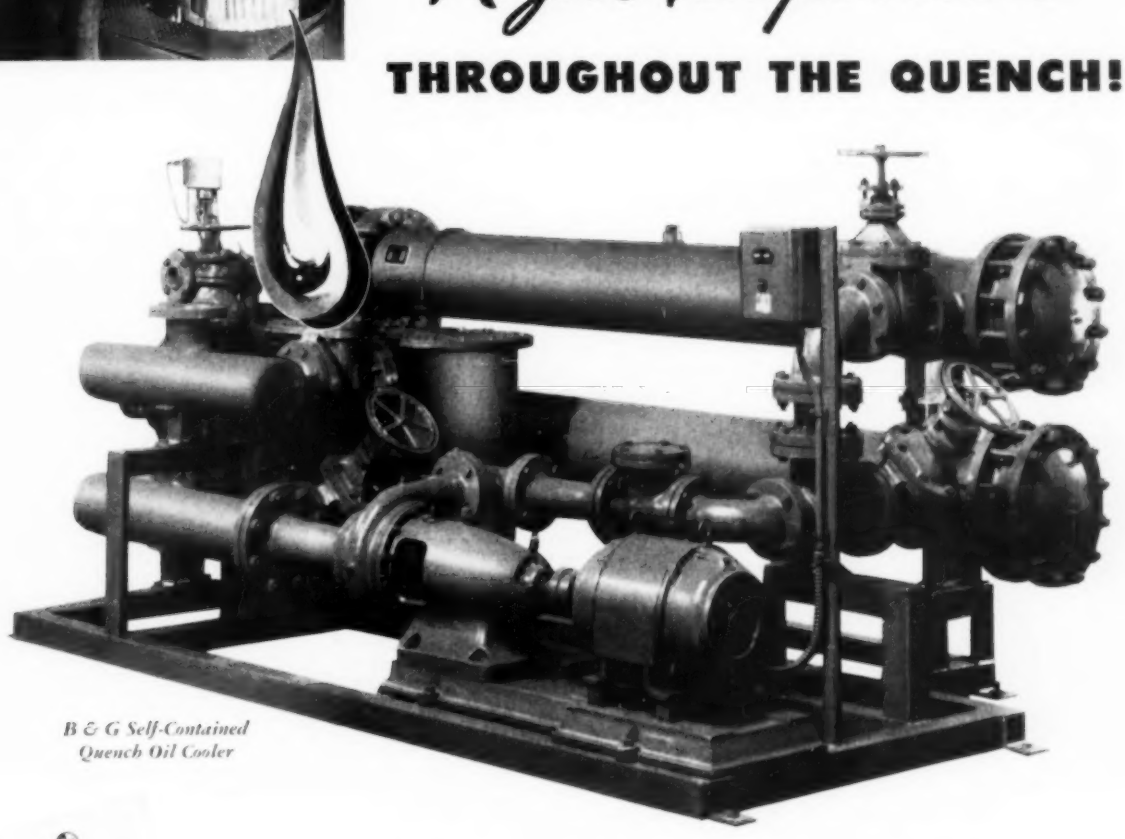

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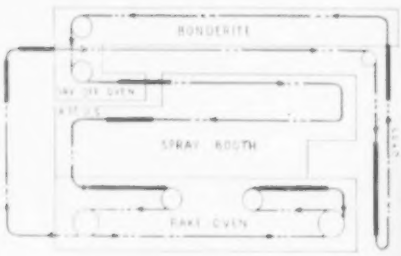


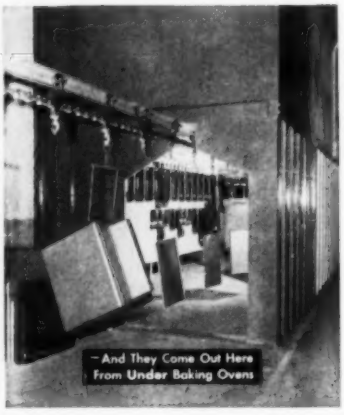


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## Recent Microscopical Techniques in Metallurgy

*(Continued from p. 182)*

is of advantage when coarse-grained photographic material is used; it is also easy on eyes. Eyepieces of 15× are advantageous for examination of rough surfaces when considerable depth of focus and consequently objectives of low numerical aperture are required.

Smallest resolvable detail is 0.61 δ/N.A., where δ is wave length of light used. The numerical aperture values of dry objectives range from 0.10 to 0.95, whereas oil immersion objectives of approximately 2-mm. focal length have about 1.30 N.A. Brightness of objectives is proportional to square of N.A. (desirable at high magnifications). For photography, objectives of highest possible power should be used; main limiting factors are depth of focus and working distance. Depth of focus of 2-mm. objective is approximately 1/2500 mm. Working distance is a fraction of focal length. Where considerable working distance is essential, reflecting objectives are preferable. They combine very good achromatism, high numerical aperture and very high working distance, and are suitable for ultraviolet photography with high resolution.

High contrast is essential for efficient use of high resolution. Contrast may be achieved by etching, which increases local variations of reflecting and light scattering coefficients. Optical methods of increasing contrast are by phase contrast, dark-field illumination, oblique illumination, polarized light, and interferometry (especially with multiple beams).

Constituents of a flat surface may reflect light at different intensities (amplitude features). Regions of differing levels (even of the same level) may reflect light of uniform intensity, but of varying optical phase. Eye and photographic plates will register only amplitude features. Contrast produced by amplitude features may be further enhanced by the following:

**Dark-Field Illumination** – This is based on differential scatter from different surface regions. The direct light beam is entirely stopped and

*(Continued on p. 186)*

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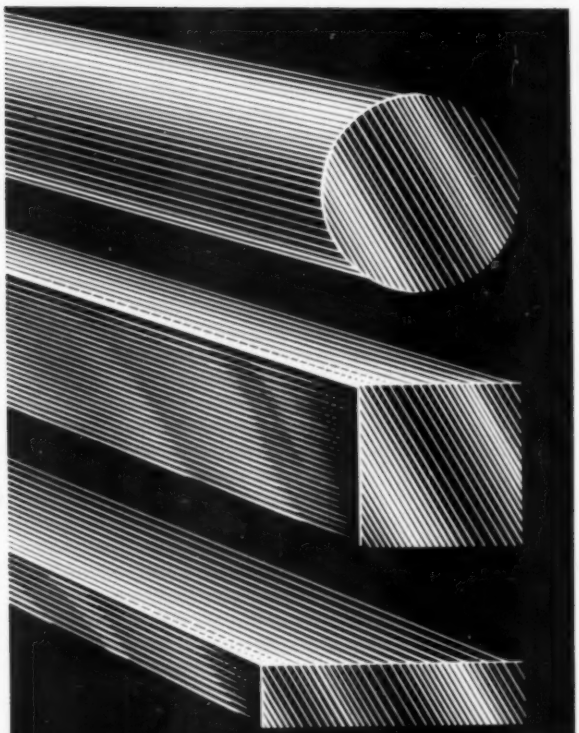

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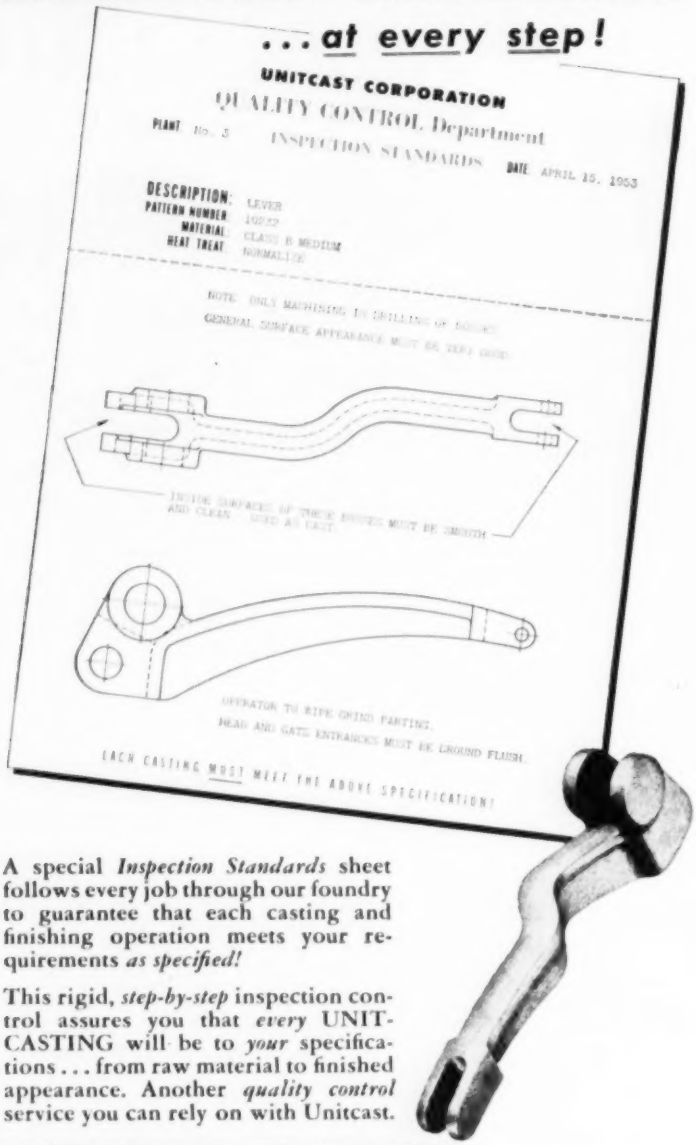


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## Recent Microscopical Techniques in Metallurgy

*(Continued from p. 184)*

illumination (hollow cone of light) is obtained by a special condenser of numerical aperture higher than that of the objective. Flat surfaces appear dark; projections, depressions, and diffuse scattering regions show as bright areas against dark background. Fine details may be falsified by diffraction.

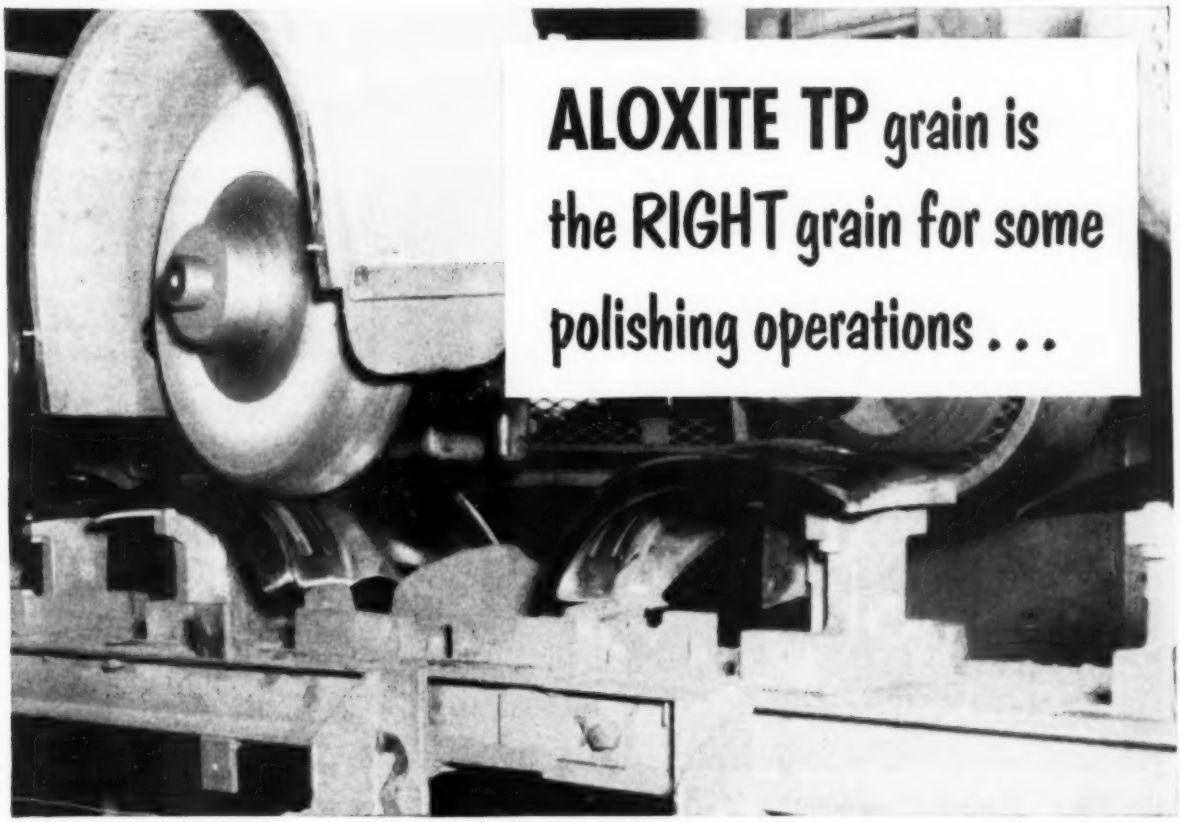
**Oblique Illumination** – For low powers the Lieberkuhn types of parabolic mirror attachments are satisfactory. For work at higher powers illuminating beam is moved off center. Diffraction may falsify details.

**Polarization** – Plain polarized light reflected from anisotropic crystals becomes elliptically polarized. Under crossed polarizers the different polarizing regions are seen at different brightnesses.

Contrast between optical phase features is obtained by phase contrast and interferometry. The first reveals differences in level small enough to produce diffraction. The direct and diffracted reflected light beams combine to produce the image. By means of a special "wave plate", diffracted beams are retarded by a quarter of a wave length relative to direct beams in positive phase contrast and are advanced by the same amount in negative phase contrast. Small differences in level, producing additional small retardation of diffracted beams, appear dark or bright respectively. Phase contrast reveals clearly features smaller than 1/10 of a wave length. Falsification of structure may occur, especially at sharp edges. Phase plates of different opacity, or equipped with a polarizing annulus, further improve contrast by adjusting relative intensities of direct and retarded beams.

**Interferometry** – By using multiple parallel beams of monochromatic light, this technique begins to enhance contrast when differences in the height of surface features are about 5 A. Only reflecting surfaces may be examined, but mat and poorly reflecting specimens can be covered by an evaporated coating of silver or aluminum (the surface being contoured to practically molecular dimensions). Surface of the sample is held close to a parallel thin

*(Continued on p. 188)*



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| ALOXITE TPT<br>Aluminum Oxide | Tough, sharp.<br>Grits 16 through 100. | Polishing operations involving removal of large amounts of metal. |
| ALOXITE TPL<br>Aluminum Oxide | Very sharp, friable.<br>Grits 16 through 220. | Polishing low tensile strength metals—copper, brass, bronze, aluminum. |
| ALOXITE TPC<br>Aluminum Oxide | Medium sharp.<br>Grits 16 through 220. | General purpose polishing grain—for removal of small amounts of metal. |
| ALOXITE TPW<br>Aluminum Oxide | Powder.<br>Grits 240 through 1000. | As the abrasive in paste heading of polishing wheels and belts. |
| CARBORUNDUM RA<br>Silicon Carbide | Sharp, very friable.<br>Grits 10 through 240. | Polishing cast iron. |
| CARBORUNDUM RA<br>Silicon Carbide | Powder.<br>Grits 280 through 600. | General purpose polishing. |

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## Recent Microscopical Techniques in Metallurgy

*(Continued from p. 186)*

plate of polished silvered glass, and the resulting interference fringes reveal level variations. Contrast may be increased by adjusting the wave length or angle of incidence of illuminating beams. This method is not limited to small level differences and may be used to obtain numerical information of level variation.

### TOPOGRAPHY

By "topography" is meant the measurement of height and depth features, details of importance in the machining of metals, the testing of hardness of metals, surface wear, grain structure and etching characteristics. Four methods have been developed for accurate measurement of height and depth features; these are interferometry (two-beam and multiple-beam), electron microscopy, stylus instruments, and the Schmaltz light cut.

**Interferometry** — The two-beam method uses a special microscope with two objectives at right angles to receive the main light beam which is split into corresponding angles. The resulting beams are reflected both from the specimen and from a separate optical flat; they interfere, producing broad fringes. Magnifications in extension approach 1000× and depths of 250 A may be evaluated with this method.

When specimen and a thin optical flat are close together, and slightly tilted and illuminated by multiple beams of parallel monochromatic light, interference produces very sharp fringes which are true contour lines of the surface. From deformation of the lines, variations in height of only 25 A can be evaluated. Combination of interference microscope and spectroscope with illumination of specimen by white light can solve more difficult problems than interference microscope and monochromatic illumination. The multiple-beam method is not suitable for high magnifications in extension (over 200 or 300×).

**Electron Microscope** — When the stereoscopic method is used, the electron microscope can give resolutions in depth to about 100 A.

*(Continued on p. 190)*

# 95%

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## Recent Microscopical Techniques in Metallurgy

*(Continued from p. 188)*

**Stylus Instruments** – These magnify depth variation about 20,000×. Magnification in extension is normally about 200×. They examine only very narrow bands of the surface, and may lead to serious errors.

**Light-Cut Methods** – An image of a narrow slit is projected at 45° by a microscope objective on a surface being examined and this reflected beam is viewed with a separate microscope. The arrangement converts a profile in depth into a line pattern in extension. Magnification in extension is usually limited to 400×; magnification of profile variations will then be approximately 650×.

Using special baffles, a similar effect may be obtained by a single objective. Monochromatic light will then permit a magnification of 2000×. Light cut reveals only a narrow band on the examined surface (bright and often deformed line on dark background).

Projecting shadows of a series of opaque lines instead of an image of the slit show the contour of the examined surface in the form of dark lines on a bright background. Identification of surface details is easy. Resolution of 25-micron differences is feasible. S. J. MAJKA

## Welding for Low Temperatures*

THE QUALIFICATION of metals for service at subzero temperatures in unfired pressure vessels fabricated under the A.S.M.E. code is determined by means of the standard Charpy keyhole notched bar prescribed by paragraph U-142. The acceptable minimum value at a given temperature is 15 ft-lb., without reference to character of fracture or slope of the transition curve. In order to fabricate such metals by welding, it is essential that proper welding electrodes be used to obtain weld metals and welded joints having properties which conform to these requirements.

*(Continued on p. 192)*

*Digest of "Welding for Low-Temperature Service", by Robert W. Bennett, *Alco Products Review*, Vol. 2, Winter 1953, p. 4-15.

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## Welding for Low Temperatures

*(Continued from p. 190)*

For operation at service temperatures of −50° F. or somewhat above, carbon steels of fine-grain microstructure are generally used. For operation at temperatures down to −150° F., low-alloy steels containing about ¾% each of chromium, copper and nickel (with and without cobalt) or the 2½ to 3½% nickel steels are used. In certain applications the austenitic 18-8 type steels have been used. For service at temperatures below −150° F. austenitic steels, copper, copper alloys and aluminum alloys are used and such metals are not necessarily qualified by the Charpy test.

While a discussion of transition temperature and other basic metallurgical aspects of the plate material are regarded as outside the scope of this paper, the author has considered those factors which are applicable from the welding standpoint.

Testing of the weld metal and welded joint as prescribed by paragraph U-68, Section VIII, of the A.S.M.E. code involves a weld-metal tension test, a bend and a tension test of the joint, and a Charpy keyhole test of weld metal and heat affected zone.

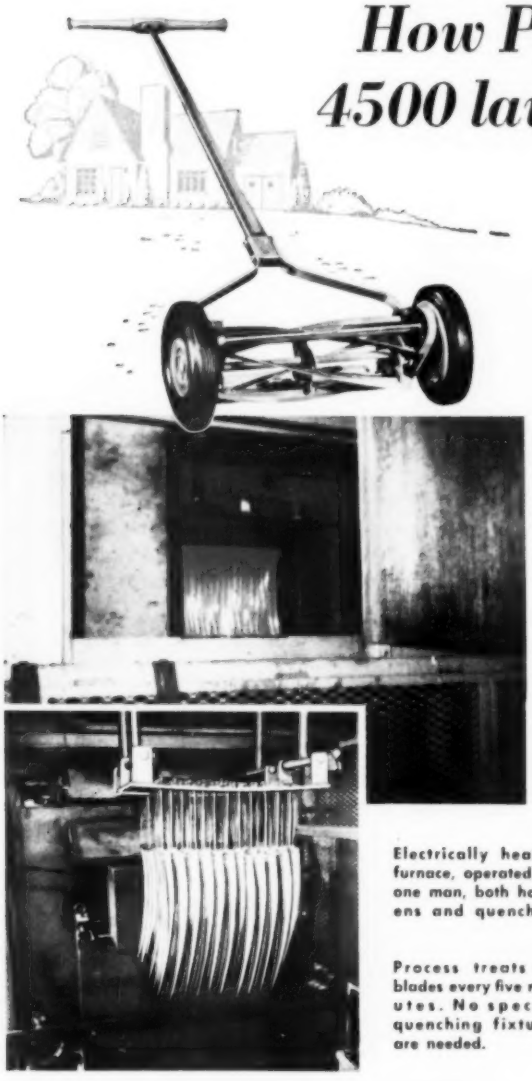
Since the room-temperature test results usually meet the minimum code requirements without difficulty, major attention is focused on the Charpy performance at the prescribed minimum temperature. If the welding heat exerts a deleterious effect on the metallurgical properties of the base metal in the heat affected zone, a brittle fracture will result in the Charpy test at subzero temperature and the energy value generally will be below the 15 ft-lb. minimum. Consistent performance of this sort may be attributed to a deficient response of the base material to the welding operation.

When testing the base material, a wide deviation of Charpy results is indicative that the material is being tested in the transition range. Such a condition generally contributes to the Charpy value, in the weld heat affected zone, falling below the required 15 ft-lb. minimum at the subzero temperature prescribed. This circumstance points to the im-

*(Continued on p. 194)*

# *The Yard-Man Story:*

# *How Park Salt Baths harden 4500 lawnmower blades a day!*



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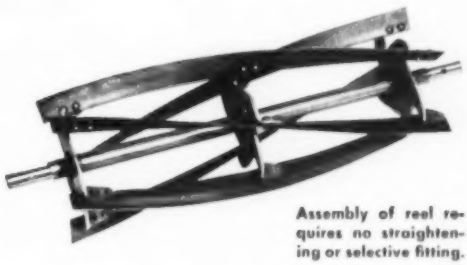

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## Welding for Low Temperatures

*(Continued from p. 192)*

portance of the quality of the base material in producing quality pressure vessels by welding.

In this investigation of low-temperature weld properties some eleven brands of electrodes were tested. Nine of these brands were of the E8015 and E8016 classes, having a low-hydrogen lime-type covering. These electrodes were dried for 1 hr. at 600° F. and stored in a desiccated cabinet until used. Two brands were of the E7020 class, commonly termed "hot rod" type, which were used directly from their container.

The base metal used was low-alloy plate of 1 in. thickness, of chromium-copper-nickel composition, having a single-U groove for the welded joint. The significant details of this groove were as follows:

Bevel Angle 9°
Root Face $\frac{1}{8}$ in.
Root Radius $\frac{1}{16}$ in.
Root Opening $\frac{1}{8}$ in.

Specific details of the welding tests are as follows:

Electrode size — $\frac{5}{32}$ in., except for one brand which was $\frac{1}{4}$ in.
Metal deposition — stringer bead for the E8015 and E8016, weave for the E7020.
Initial plate temperature — room temperature.
Interpass temperature — 100 to 200° F.
Test plates were clamped during welding.
Arc interruptions were all within the center or middle third of the test-weld length.
Back of the joint was ground to sound weld metal before back-welding.
Weld reinforcement was ground off before radiographing.
Test welds were stress relieved at 1150° F. for 1 hr.

From the preliminary Charpy check tests at −150° F., the E7020 electrodes were considered not suitable for this low-temperature service since a number of the individual specimens gave values under 15 ft-lb. These electrodes were eliminated from further testing along with one of the low-hydrogen covered electrodes which gave a weld metal with low Charpy values.

Testing of the mechanical properties of weld metals from the eight remaining brands showed that three failed to meet the requirements for bend test at room temperature. At this point in the investigation, two

brands were removed from further consideration because they were no longer commercially available.

Shop tests were made of the six remaining brands of low-hydrogen covered electrodes by making circumferential butt (girth) welds in 18-in. diameter pipe (0.562 in. wall thickness) of A.S.T.M. A106 carbon steel. The joint groove was a single-U and the test assembly was rotated during welding so that all welds were made in the "flat" position. Weld metal was deposited by a string-bead technique with a "stop and start" every 6 in. to test for crater porosity. The inside of the joint was gas-gouged about $\frac{3}{8}$ in. deep and a back weld deposited. After grinding off exterior and interior weld reinforcements, each test weld was completely radiographed.

One electrode brand, which had previously shown unsatisfactory bend test results with high tensile properties, exhibited an excessive amount of slag in the weld and was eliminated from further testing.

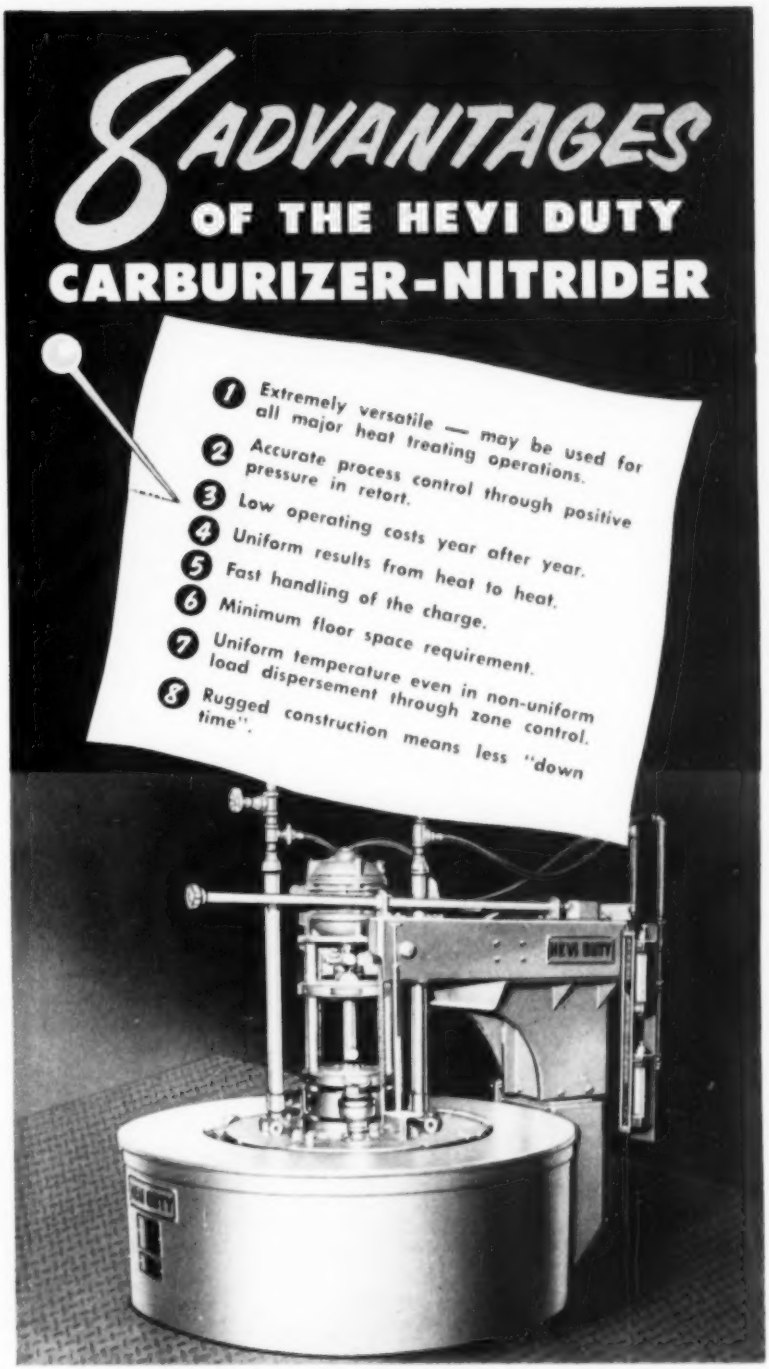
In order to evaluate further the performance of the remaining five brands of electrodes, a nozzle-weld test was made. This test consisted of welding a 6½-in. diameter carbon steel pipe of 0.500 in. wall into the 18-in. pipe used for the girth weld tests. A single-V groove was used having a $\frac{1}{16}$-in. root face and an average root opening of $\frac{3}{4}$ in. The welding technique was similar to that used for the girth welds. When welding was completed the 6½-in. nozzle was faced off flush with the shell surfaces and the welded joint radiographed.

In this test two of the five brands of electrodes gave welds containing considerable entrapped slag. Since these two brands also had exhibited unsatisfactory bend-test results, they were eliminated.

It was then concluded that the three brands left were most suitable for obtaining the desired room-temperature mechanical properties and the Charpy values required at −150° F. The author indicates that some 43,000 lb. of one of these brands and about 1000 lb. of another have since been used with consistently satisfactory results in the fabrication of pressure vessels. The substantial reduction in weld repairs has reduced fabricating costs.

With the thought that it is eco-

(Continued on p. 196)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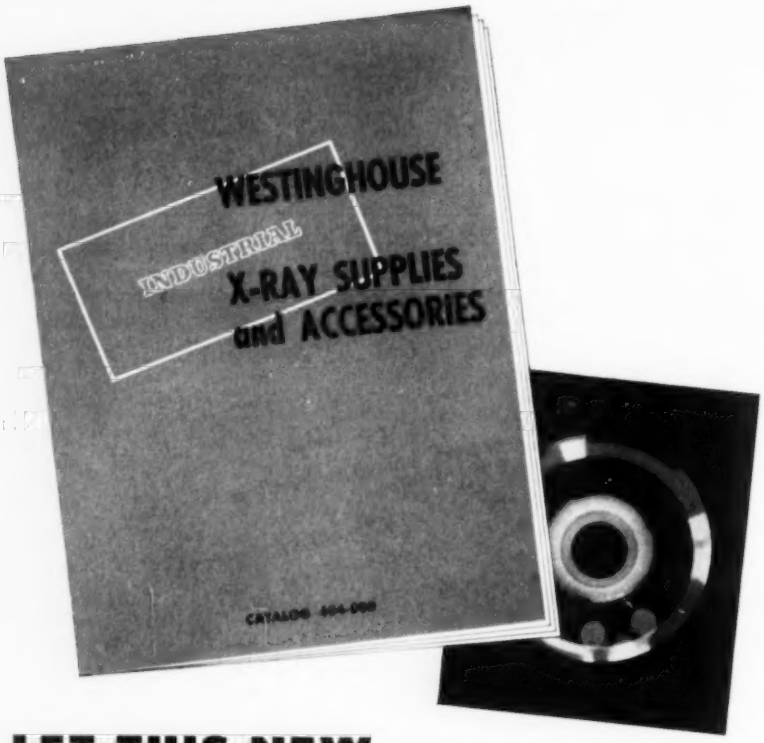


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## Welding for Low Temperatures

*(Continued from p. 193)*

nomically unsound to use the more expensive materials, if the temperature and other service conditions do not warrant, a transition temperature study was made of weld metals of the E6010, E6020, E7020 and E8016 classes to determine the most economical weld metals to meet code requirements. Qualified shop welding procedures were used for welding A201 carbon steel, A203 (3½%) nickel steel and the low-alloy chromium-copper-nickel steel.

From the transition curves of these weld metals and on the basis of the A.S.M.E. code requirement for 15 ft-lb. minimum, it is concluded that, in killed carbon steels, the E6020 electrodes will deposit weld metal satisfactory for service to −40° F., and the E7020 electrodes qualify for service to −60° F. For service down to −150° F., the E8016 electrode has been consistently satisfactory.

Check tests of E6010 electrode and submerged-arc (Oxyweld No. 40) were also made. While the E6010 showed good results to −80° F., it is not extensively used because of cost considerations, particularly where the work can be positioned. The submerged-arc weld metal did not pass the Charpy test primarily because of its dendritic microstructure.

Correlation of the metallurgical structure of weld metal with Charpy results indicated that a fine-grained weld metal is essential for optimum notch toughness. Where the base materials are uniform and show good notch toughness, the Charpy notched-bar tests of the heat affected zone are generally satisfactory.

W. L. Warner

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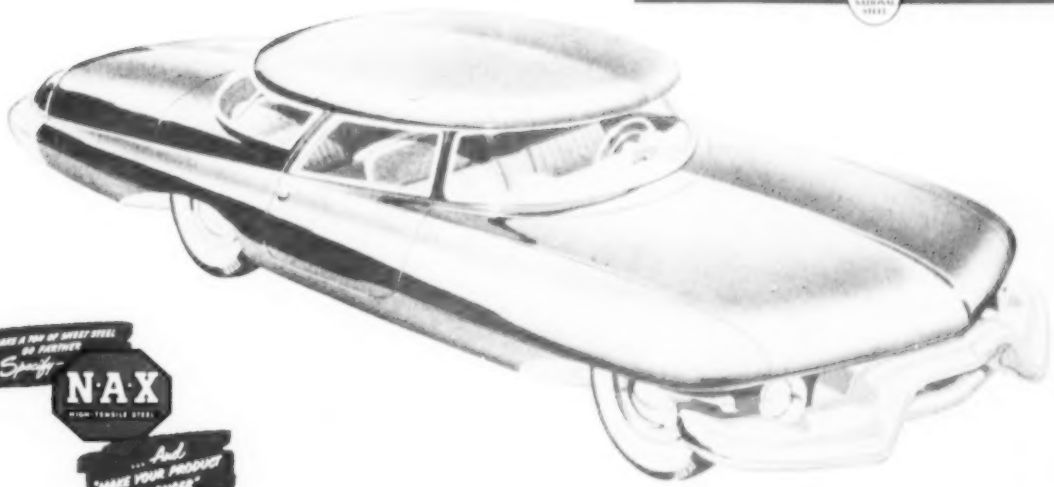

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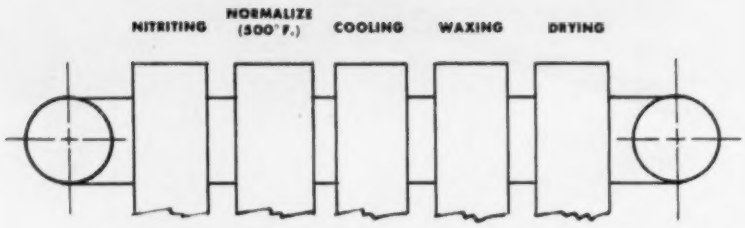


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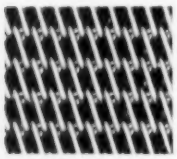

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# Electrolytically-Assisted Diamond Wheel Grinding of Carbides Is "Promising"*

COMBINATION of diamond-wheel grinding with electrolytic assist for off-hand finish grinding of single-point cemented carbide tools (see *Metal Progress* for August 1952, p. 89) is showing promise as test programs under way for the past year become progressively evaluated. Conservation of 80 to 90% of the amount of diamond bort consumed by conventional vitrified-bonded diamond wheels appears possible, although investigators are cautious about making any unqualified claims until additional comparative tests have been concluded.

Electrolytically-assisted diamond-wheel grinding of carbide tools, briefly, is a method of stock removal wherein conventional grinding with a diamond wheel is supplemented by simultaneous electrochemical erosion or decomposition of the carbide. The tool or workpiece, made positive in a direct-current electrical circuit, is separated a minute amount from the metal bond of the wheel, itself negative, while a suitable electrolyte flows between them. Diamond particles act both as an abrasive and as non-conducting spacers to prevent metal-to-metal contact between the work and the metallic wheel bond during electrolysis.

In first experimental set-ups, the electrolyte supply tube was flared and a flow of liquid in a wide ribbon was directed to the wheel above the area of contact. However, in later runs, the electrolyte was directed toward the center of the wheel, from which position it moved across the wheel face in a thin film by centrifugal force. The change was dictated by excessive erosion of the top edge of the tool, caused by the electrochemical action of the fluid.

Typical test results show that, with electrolytic assistance of 250 amp. per sq.in., a metal-bonded diamond wheel cuts at approximately the same rate as a vitrified-bonded diamond wheel used conventionally, at the

*(Continued on p. 200)*

*Digest of "Electrolytically-Assisted Diamond Wheel Grinding of Cemented Carbide", by N. W. Thibault and B. H. Anderson, Technical Bulletin No. 526, Norton Co., Worcester, Mass., November 1952.

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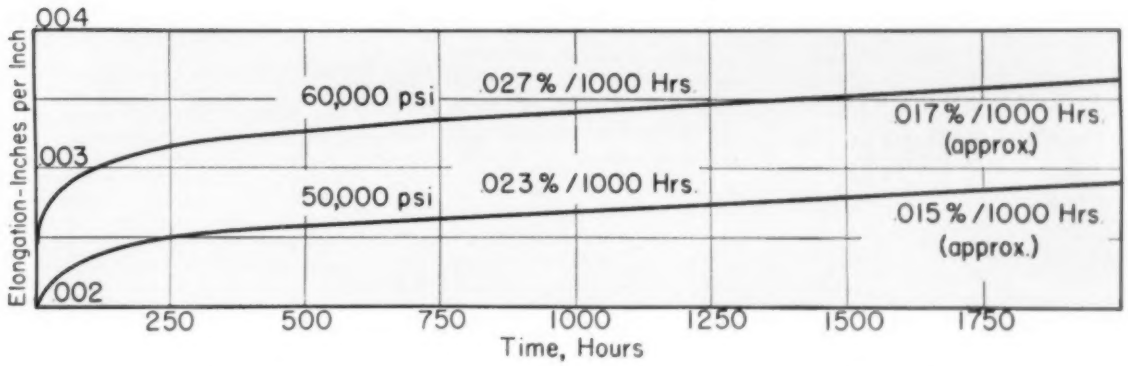


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## Electrolytically-Assisted Diamond Wheel Grinding

*(Continued from p. 198)*

same time using only 7 to 21% as much diamond. At 145 amp. per sq.in. the diamond consumption was equally low, but the rate of cut dropped one third. When current density was stepped up to 315 amp. per sq.in., arcing proved unavoidable, but the rate of cut almost doubled as compared with the same wheel operating at 250 amp.

Metal-bonded diamond wheels with electrolytic assistance gave ground tool surfaces which were entirely "mat" at current densities of 140 to 315 amp. per sq.in. and more reflective with some evidence of an abrasive scratch pattern at lower densities. Profilometer readings varied from 5 to 6 micro-in. at 80 amp. up to 9 to 12 micro-in. at 250 amp. No chipping or cracking of the carbide was noticed.

It was believed that the edge erosion referred to previously might be avoided by coating adjacent surfaces of the tool with a nonconductive protective film, preferably one which could be applied by dipping and then air dried. Many types of coatings were tried, but none proved satisfactorily adherent. Best results were achieved with the use of liquid shellac followed by a low-temperature bake. Cost of applying such coatings is a deterring factor.

Some reduction of edge erosion was realized by changing the electrolyte to "N" grade sodium silicate diluted with equal parts of water in place of the regular 5% sodium chloride plus 14% rust inhibitor "A" used in most of the electrolytic tests. However, this reduced the rate of cut by one third.

Checks on power requirements showed 440 watts drawn by a vitrified-bonded diamond wheel in conventional grinding. By using a metal-bonded wheel and electrolytic assistance, spindle power dropped to 125 watts, but an additional 514 watts was demanded by the electrolytic action at the gap, indicating a 50% increase in over-all power.

Successful electrolytic action in the grinding of single-point carbide tools appears to be contingent upon the proper combination of abrasive action and electrolysis. If the latter

*(Continued on p. 202)*

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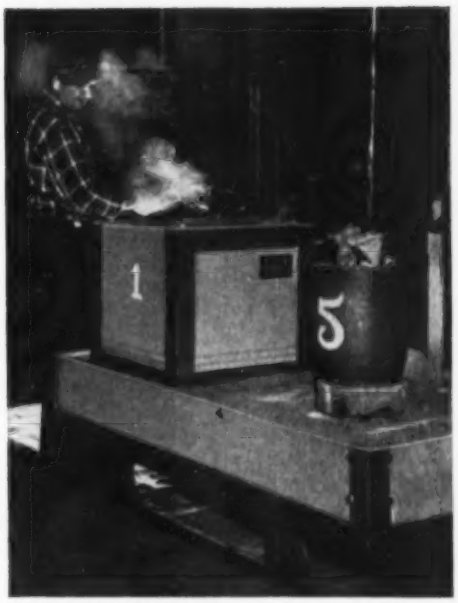

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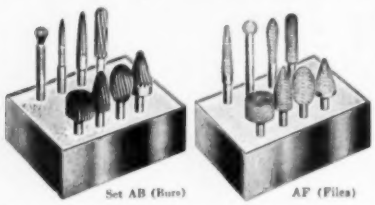

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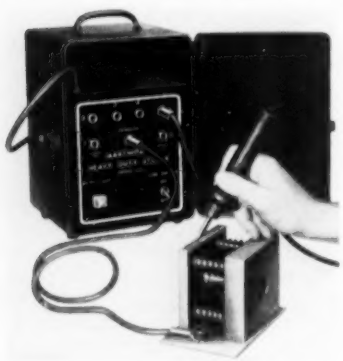

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# Electrolytically-Assisted Diamond Wheel Grinding

*(Continued from p. 200)*

is too preponderant, there is a preferential electrochemical attack on the individual constituents of the carbide, resulting in a surface enriched in the tungsten carbide phase. This surface seems to have lower conductivity than the cemented carbide itself, retarding further electrolysis and promoting attack on adjacent surfaces and edges. Removal of this enriched surface zone by abrasive action therefore must keep pace with electrolytic attack on the more susceptible metal for best results.

Full recommendation of the technique as a commercial method must await three things: *(a)* More laboratory tests of the nature just described; *(b)* confirmation of laboratory findings by field experience; and *(c)* more thorough investigation of other aspects of electrolytically-assisted diamond wheel grinding.

A. H. ALLEN

# Bearing Alloy of Iron-Silicon Brass*

AMONG THE STANDARD alloys used for bearings in Russian metal-working machinery – such as machine tools, presses and the like – are the following: Tin bronzes, of 5 to 7% Sn, 5 to 7% Zn, 2 to 4% Pb, balance Cu; 9 to 11% Sn, 0.6 to 1.0% Pb, balance Cu; also, for subordinate applications, a zinc alloy with 5% Al, 10% Cu, balance Zn.

As a cheaper substitute, a Fe-Si brass has been developed which is reported to have antifriction properties equivalent of the tin bronzes. Charge materials used are 95% brass scrap (containing 30% Zn maximum), 3% ferrosilicon (75% Si), and 2% Pb. Average composition of alloy runs 68 to 70% Cu, 25 to 27% Zn, 0.6 to 1.0% Fe, 1.7 to 2.5% Si, 1.6 to 2.0% Pb. It has an ultimate tensile strength of 40,000 to 46,000 psi., elongation 8 to 12%, and a Brinell hardness of 107 to 120. The content of Fe is critical: With less than 0.5% Fe the hardness falls to

*(Continued on p. 204)*

*Digest of "Iron-Silicon Brass as Substitute for Tin Bronzes and Zinc Alloys", by V. V. Gusyev, *Liteynoe Proizvodstvo (Foundry Production)*, 1952, No. 3, p. 29-30.


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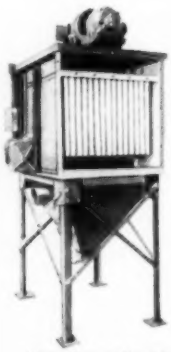

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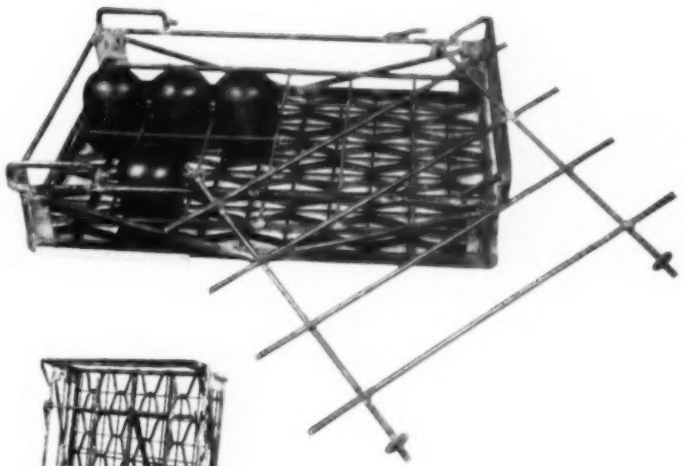

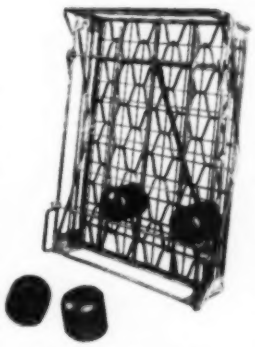

This is but one example of Rolock special shell case equipment. Other types, as well as fixtures used before the cupping operation . . . and others used after the final draw, for washing and lacquering . . . have been designed. Ask us for details.

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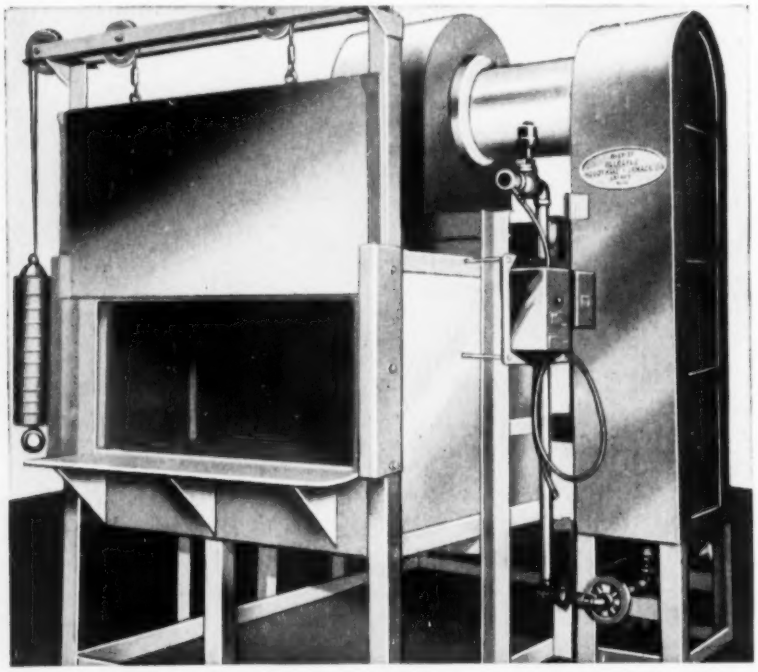

Batch-type furnace—for the heat treating of aluminum alloys—consists of atmosphere-type burner, mounted on the lower end of the combination chamber to reheat the recirculated hot air through the furnace. A High Heat insulated recirculating fan is standard equipment for recirculating the heated air. This method of heating holds temperature with little or no variation. Mounting the burner in the duct eliminates the necessity of an extra heating unit. . . . Send us your heat treating problems . . . our engineers will make a proposal without obligation.

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## Bearing Alloy of Iron-Silicon Brass

*(Continued from p. 202)*

a range of 60 to 65 Brinell, and machinability is poor; above 1% Fe the Brinell hardness is increased to between 140 and 160 and the alloy becomes brittle.

Melting can be done in any type of furnace. When a crucible furnace is used, the ferrosilicon is charged first and heated until it softens. Then the brass scrap is introduced and brought to melting. No fluxes or deoxidizers are required, since the zinc vapors keep the bath from contact with the furnace atmosphere. When the metal is completely molten, the first slag is taken off, this being followed by mixing the metal. After further heating at 2000 to 2100° F., the crucible is removed from the furnace, the slag is again skimmed off and lead is added. After a thorough mixing, the metal is poured at about 1925 to 2000° F.

The Fe-Si brass has excellent casting properties. Its contraction is 15 to 20% less than of tin bronze. It is suitable for making castings of variable wall thickness and complex configuration, and no special risers are needed. Sand or permanent metal molds may be used and the castings show no pores or blowholes.

Finally, some comparisons of relative cost of this and the conventional materials are of interest: According to the author, this alloy is 7.3 times cheaper than the 10% Sn bronze and 5.4 times than the nominally 6% Sn - 6% Zn bronze, both of which have been mentioned earlier.

It is also 20% cheaper than the Zn - 5% Al - 10% Cu alloy. (*Reviewer's remark:* Tin-containing alloys are priced nearly in proportion to their tin content.)

N. H. Polakowski

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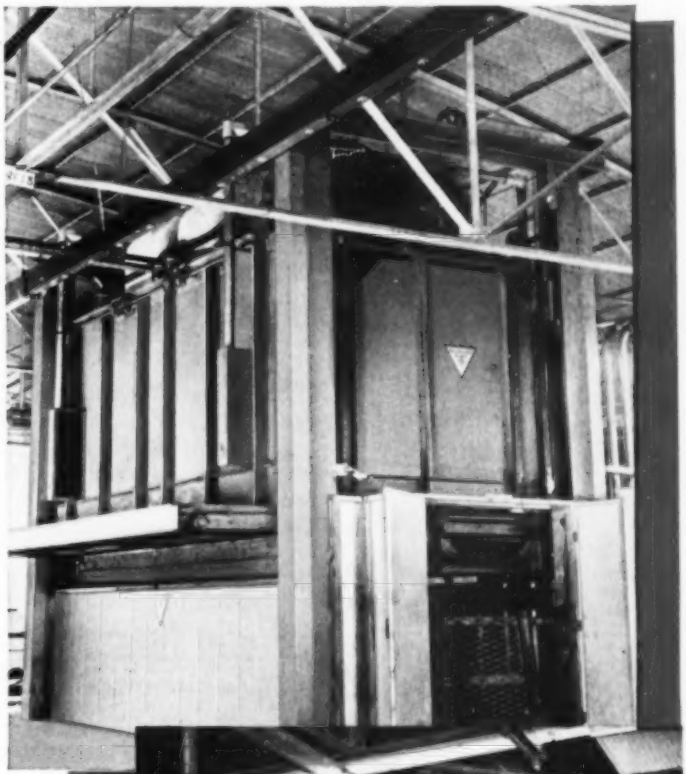

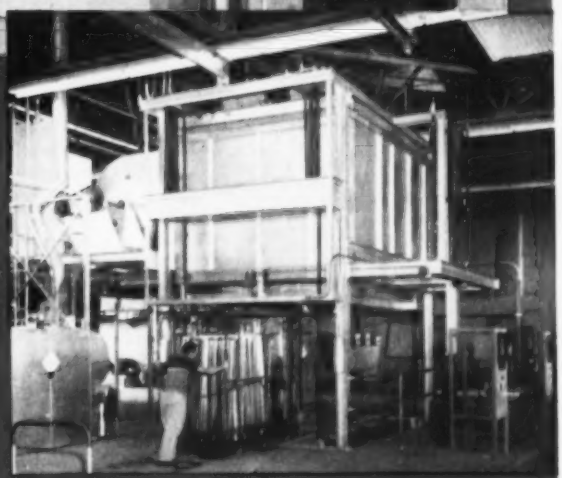

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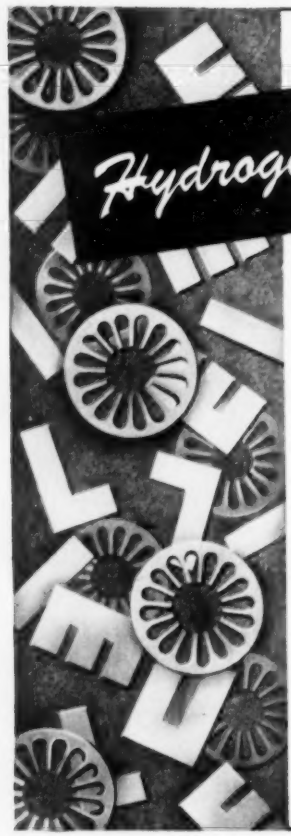

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## A Test for Properties of Bearing Alloys*

IN THIS ARTICLE on boundary lubrication for sleeve bearings, a brief résumé of the theoretical considerations is given which is followed by a description of experimental work, the results obtained thereby, together with a "Bearing Hypothesis" derived from them.

The test is conducted with a plane piece of the bearing metal across which a ball (fixed in a chuck) is made to slide while the test piece is submerged in the lubricant. The ball is pressed against the test piece under a constant load, and is drawn reciprocatingly across its surface by a connecting rod movement; speed is 72 rpm., which gives 144 starts per min., and the stroke is 127 mm. long.

With the load on the ball constant, the load at point of contact will depend upon the width of the track worked into the test piece. For white metals this figure will be between 17,000 and 21,000 psi., whereas for copper alloys it may reach 55,000 psi. With the ball chuck insulated from the test piece and a low voltage imposed on the point of contact, it is possible to follow on an oscillograph the resistance in the track developed by the reciprocating movement of the ball. A recording voltmeter registers the mean tension over the measuring point.

Results indicate that boundary lubrication is the primary effect, while fluid lubrication is secondary.

Tin-base or lead-base white metals that solidify quickly have better bearing properties than slowly solidified metal. Oxidation seems to be a necessary adjunct to the process. Deduced from the experiments is the hypothesis that the function of a sleeve bearing is conditioned by the formation of adhesive films which prevent metallic contact. These films are produced through a chemical reaction between the rubbing metals, the lubricant, and the atmosphere.

The test described is simple in execution, and takes about an hour to test a metal-oil combination. It has been possible to verify an interaction between bearing material and lubricant, and to express the result by one figure. H. J. ROAST

*Digest of "Recent Views on Bearing Properties", by Borge Lunn, *Metal Industry*, Jan. 23, 1953, p. 63-65.

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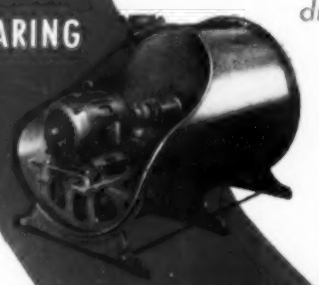

*Overhang or outboard type for coupled drive*

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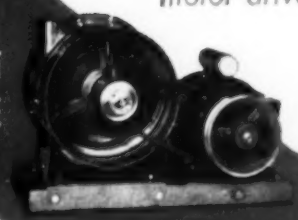

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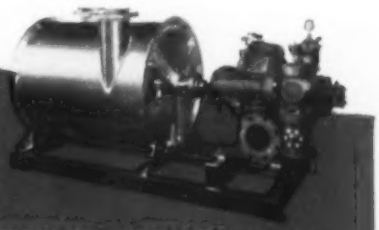

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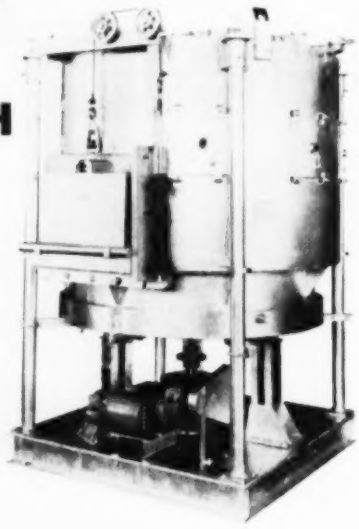

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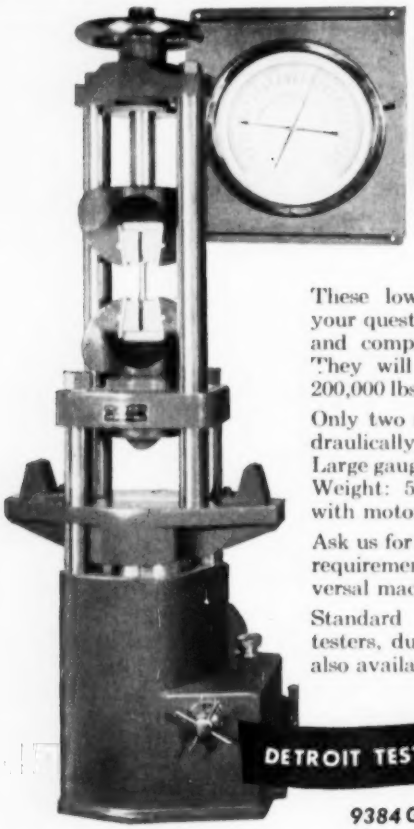

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## Electrical Resistivity Measurements Reveal Solid Solubility*

THE EFFECT on creep properties of changes in the composition, within the solid-solution range, of binary aluminum-silver alloys has been investigated recently by the authors. Their program required the creep testing of alloys containing 0.5 to 8% pure silver in super-pure aluminum. To carry out the experiments in the solid-solution state, it was necessary to know accurately the limits of solubility of silver in aluminum over the range 200 to 750° F.

In designing the experiments to obtain data for the construction of the solubility curve, Rotherham and Larke realized that the extended times for heat treatment which are necessary at low temperatures to produce microscopically visible structural changes would present difficulties. It was decided, therefore, to develop a technique capable of indicating changes in electrical resistivity on crossing a phase boundary. It was hoped that this method might be sensitive to the small structural changes which occur before any change is microscopically visible and which take place in a relatively short time during heat treatment. These two approaches, the microscopical examination of suitably heat treated samples and the measurements of electrical resistivity, have been used throughout the investigation. The micrographical data extend over the range 400 to 750° F. (from approximately 1 to 8% Ag) and changes in resistivity have been observed over the range of 200 to 650° F. (0.63 to 5.10% Ag). Substantial agreement was obtained between the two methods over the range of the investigation. The solid solubility of silver in aluminum is greater at higher temperatures and less at lower temperatures than previously reported. The limit of solubility of silver at room temperature is indicated (by extrapolation) as being approximately 0.6%.

Microscopical examination of the precipitated phase shows a well-

*(Continued on p. 210)*

*Digest of "The Solid Solubility of Silver in Aluminum", by L. Rotherham and L. W. Larke, *Journal* of the Institute of Metals, Vol. 81, 1952-53, p. 67.

# AJAXOMATIC POURING UNIT

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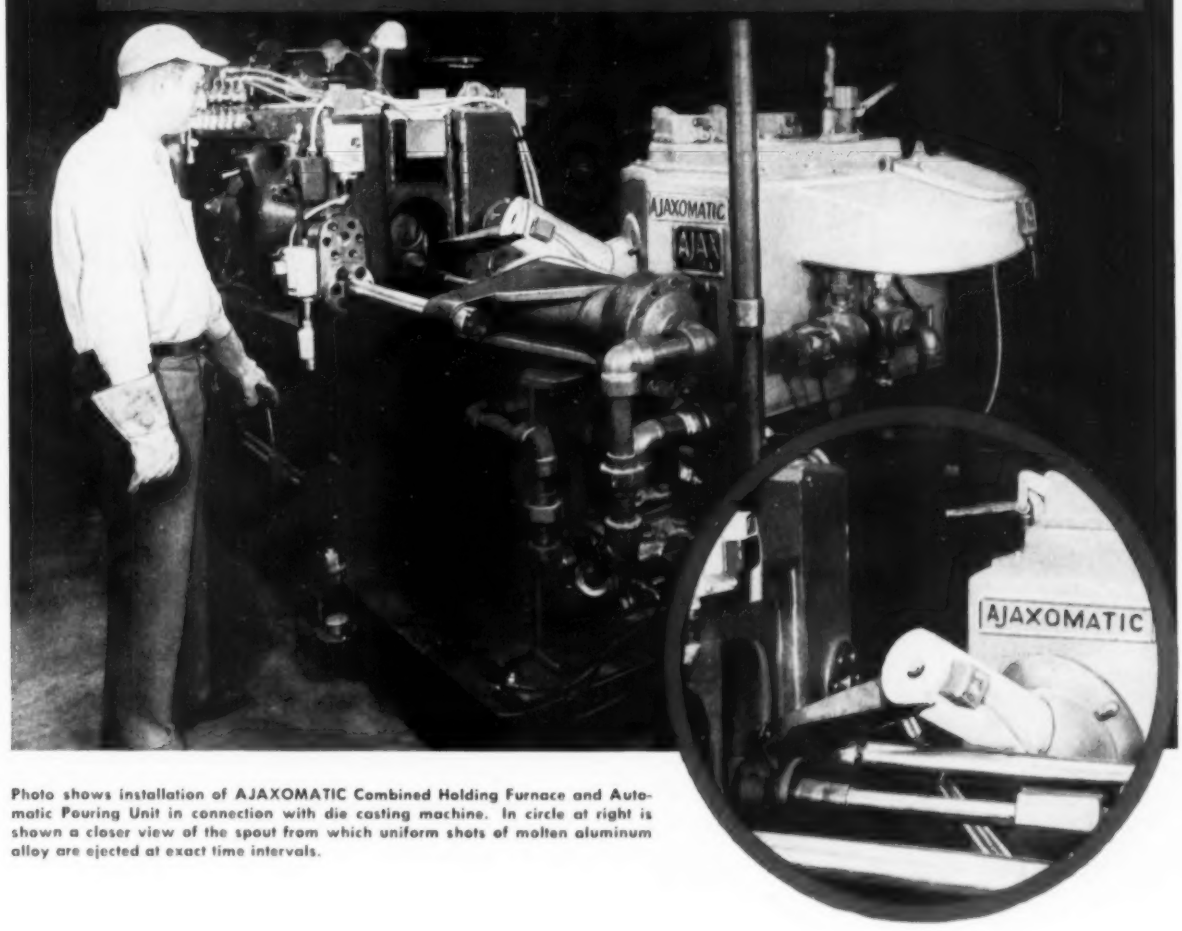


Photo shows installation of AJAXOMATIC Combined Holding Furnace and Automatic Pouring Unit in connection with die casting machine. In circle at right is shown a closer view of the spout from which uniform shots of molten aluminum alloy are ejected at exact time intervals.

**NOW completely automatic die casting of aluminum alloys is possible in smaller quantities than formerly, and at reduced cost. This fact should be of special interest to the manufacturer who has die casting machines in operation and is doing hand ladling. The unit is entirely sealed, the operator feels no heat, accident hazard is eliminated.**

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## Resistivity Measurements Reveal Solid Solubility

*(Continued from p. 208)*

defined Widmanstätten figure. This type of precipitate, which is not an intermetallic compound but an intermediate solid solution, is deposited in the form of plates on the (111) planes. When the alloys are etched with a suitable reagent, attack in the grain boundaries in the form of a discontinuous line of globules is the initial evidence of departure from the solid-solution state.

In the nominal 1% alloy, the grain-boundary precipitate after aging for 450 hr. at 400° F. was not microscopically visible, although the resistivity technique indicated that a change had taken place. Electron micrographs, taken after electrolytic polishing in a perchloric acid electrolyte, revealed the presence of a precipitate which became microscopically visible after further aging.

In the solid-solution state, the change in electrical resistivity plotted against percentage of silver gives a straight-line relationship. No significant alterations in resistivity have been observed in the materials on resolution treatment after aging. With the alloys of lower silver content, changes in resistivity on aging occurred before there was microscopical evidence of a second phase.

TOM BISHOP

## Pig Iron Smelting in Low-Shaft Furnaces*

THIS PAPER reviews in some detail the production of pig iron with the Krupp-Renn, Stuerzelberg, Lohse and the various low-shaft blast furnaces which have been investigated in Sweden, Italy and Germany during the last 15 years. Most of these (as pilot plants and methods) were introduced to handle low-grade iron ores and low-grade solid fuel such as coke breeze, high ash coals and lignite. The increasing scarcity of high-grade coking coals suitable for the manufacture of good quality metallurgical coke, necessary for use in the standard blast furnace, has caused a

*Digest of "Pig Iron Smelting Without Metallurgical Coke", by W. W. Krebs and D. Jagat Ram, *Transactions*, India Institute of Metals, Vol. 5, 1951, p. 51-76.

revived interest in these processes in those countries where there are only meager deposits of coking coal. Although India has perhaps the largest known deposits of high-grade iron ore, it is quite deficient in coking coal reserves, and the operation of standard high-shaft blast furnaces in that country is costly due to the high cost of imported coal.

The first section of the paper describes equipment for making pig iron in a somewhat complex furnace arrangement wherein the cheap coal and iron ore mixture is given a pre-smelting reduction treatment in a rotary kiln similar to that used in the Krupp-Renn process. Limestone or dolomite is calcined in a smaller rotary kiln placed below the reduction kiln, and the reduced ore and calcined lime are discharged into a mixing shaft and then dumped into one of two rotary iron smelting furnaces placed at right angles to the axes of the two rotary kilns. The smelting furnaces are heated with burners using powdered coal and preheated air (1470° F.), and the hot gases from this furnace pass through the reduction kiln and calcining kiln into hot-blast stoves and finally to a waste heat boiler. This is a rather complex assembly of furnaces with numerous gas connections and seals between the rotating units.

In the reduction furnace the coal and ore mixture is charged into the upper end and is gradually heated to 1830° F. at the outlet. In order to reduce dust loss, the charge is passed over ¼-in. screens, and all fine coal and ore dust is pelletized before charging. Coke breeze, fine coal, or lignite may be used as the source of carbon. The coal-ore mix is heated to a range of 1830 to 1920° F., as is the lime. The iron ore is reduced to sponge iron and ferrous oxide in this operation.

On its discharge from the primary reduction kiln the preheated burden is mixed with the burned lime leaving the calcining kiln and travels over a revolving, water-cooled chute into one or the other of the rotary melting furnaces of the Stuerzelberg-type. As shown in the drawing in the paper, both the rotary kilns, which are arranged one above the other, lead into a common refractory-lined header. The charging sides of the two other basic melting furnaces, which are at floor level, extend into

*(Continued on p. 212)*

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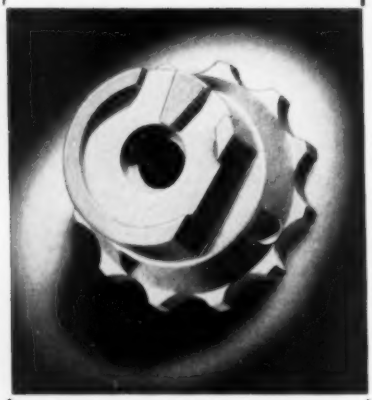

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## Pig Iron Smelting in Low-Shaft Furnaces

*(Continued from p. 211)*

the same mixing header on opposite sides. Gas-tight seals and valves are needed at the junction with the smelting furnaces.

The rotary smelting furnaces are basic lined to control the sulphur. They are fired with powdered coal or oil and a neutral flame is used. Air is preheated to 1470° F., and temperatures of 2900 to 3100° F. are said to be developed. Fuel consumption is stated to be 1 ton of coal per ton of pig iron and the melting rate is 3.5 tons of pig iron per hour. The amount of coal mixed with the ore charge is not given, nor are the analyses of ores, slags and pig iron produced or of the gases at various stages of operation. Apparently most of the data was obtained from results at the original Krupp-Renn plant in Berlin. The paper states that this (Krupp-Renn) plant was dismantled in 1945 by the Russians and that all operating records have disappeared.

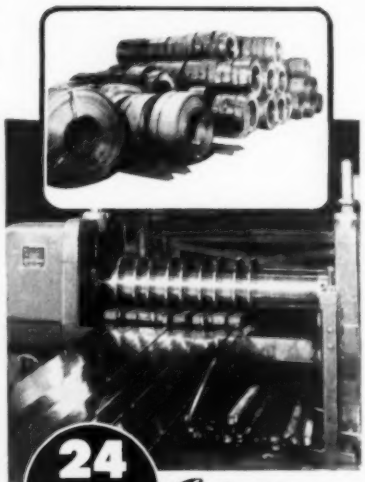
No dimensions of the equipment are shown in the drawings of this layout. The smelting furnaces are about 26 ft. long and 14 ft. diameter (outside), and the kiln scales to 280 ft. long, 10 ft. diameter; the lime kiln is 50 ft. long, 8 ft. diameter. With iron ore of 50% iron content, the pig iron production of this assembly is said to be 150 to 165 tons per day.

The advantages claimed for this process are that it can use low-grade coals and lignites for fuel, produces a low-sulphur pig iron similar to charcoal pig, and it avoids the refractory difficulty of the Krupp-Renn kiln, since the ore-coal mix is heated to only about 1800° F. instead of 2280 or 2370° F. as in the Krupp-Renn process. One of the worst problems of the latter was due to the formation of a pasty mass of sponge iron ("lupps") near the outlet which reduced the refractory life in this part of the kiln.

### LOW-SHAFT BLAST FURNACES

The main features of the operation of the low-shaft blast furnace are the use of a fine, low-grade fuel instead of metallurgical coke, a pelletized or briquetted charge with the ore and reducing fuel intimately mixed be-

*(Continued on p. 214)*

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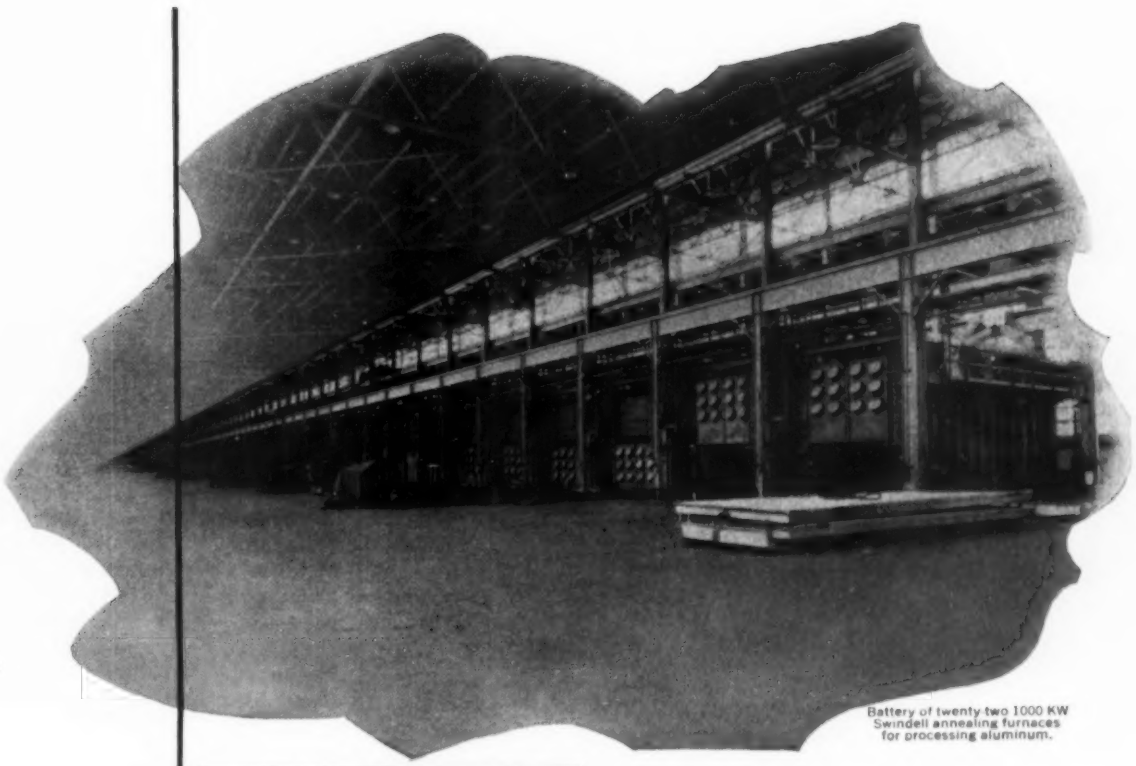

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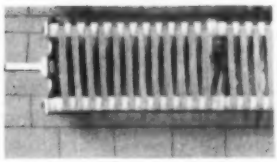

Typical Nichrome ribbon heater assembly, installed in the furnaces shown above.

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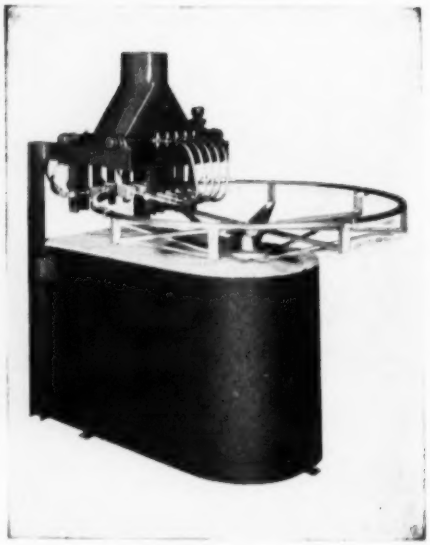

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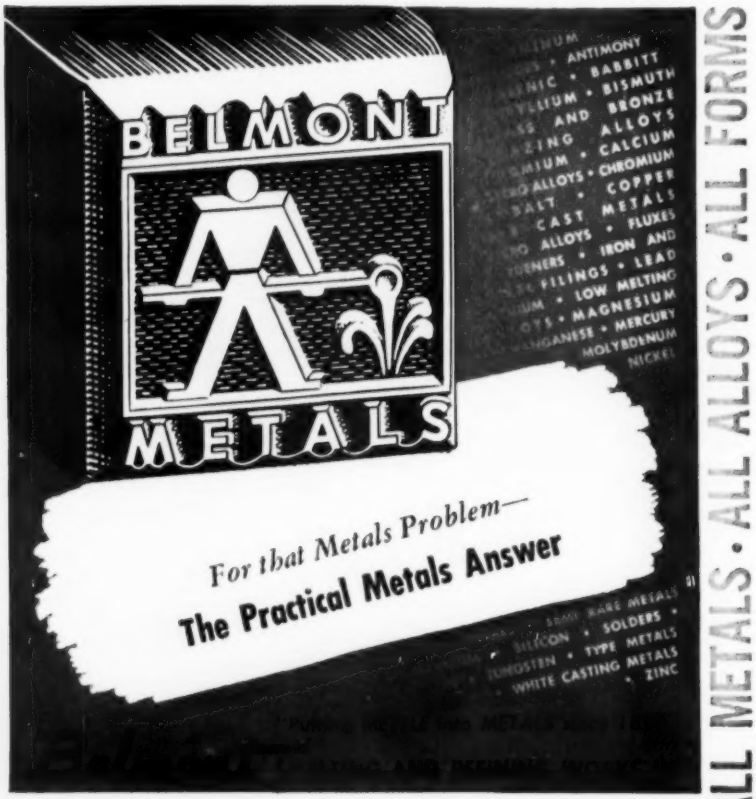




## Pig Iron Smelting in Low-Shaft Furnaces

*(Continued from p. 212)*

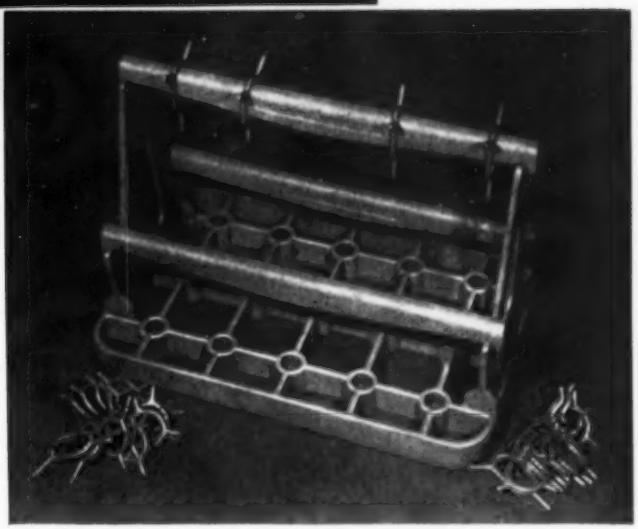
fore charging, and the injection of oxygen into the blast. The standard high-shaft blast furnace is essentially dependent on a strong cellular coke and, when such a coke is not available, there is no proper support for the heavy charge.

The charging of ore-coal briquettes or the enrichment of the blast with oxygen also serves to reduce the top temperature of the effluent gases to produce a gas of low nitrogen content. While ordinary blast-furnace gas has a heating value of about 100 B.t.u. per cu.ft., the outgoing gas from the low-shaft furnace has a heating value of 170 to 280 B.t.u. per cu.ft. Such a furnace is essentially a gas producer, but enough heat is generated in the hearth to melt both the iron and slag. Extensive trials with this type of furnace have been made on low-grade ores in Germany at Trostberg, on pyrite cinder in Sinigo, Italy; also, an experimental furnace is now being built near Liége, Belgium. The Italian furnace had an internal diameter of 11.5 ft. in the hearth area, 16 ft. diameter at the top and was 25 ft. in height. When using a pelletized charge of roasted pyrite of 57% iron content with 4 tons of raw lignite (48% C) per ton of iron and a blast of 50 to 60% oxygen, this furnace produced 200 to 240 tons per day. The gas it produced had an average heating value of 280 B.t.u. Although no analysis of the pig iron, slag or gas is given in the paper, it is stated that the gas has valuable composition for the synthesis of chemical compounds such as are made by the Fischer-Tropsch process.

The paper summarizes this situation by stating that both rotary reduction—rotary smelting modification of the Krupp-Renn process, and the low-shaft, oxygen-enriched blast furnaces are adaptable to conditions in India, since these methods enable the production of pig iron from fine ores and low-grade, non-coking coals. The construction of both types of equipment on a pilot-plant scale is proposed so as to investigate the feasibility of the process in India. No costs or economic discussion is contained in the paper.

E. C. Wright

# GAS CARBURIZING TRAYS



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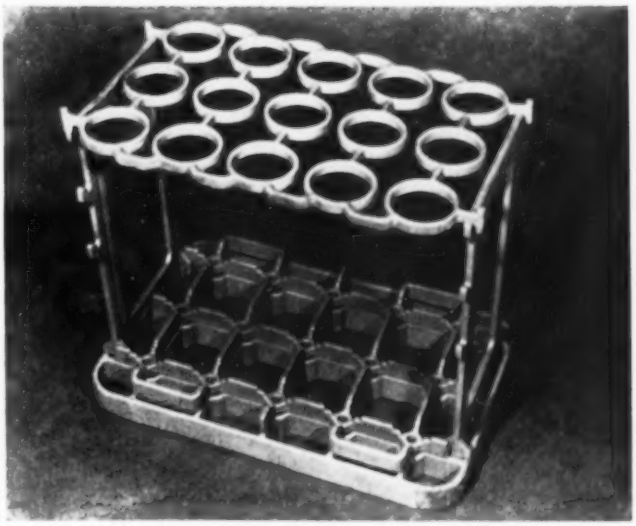

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## Redrawing of Cylindrical Cups*

In the direct production of cups from flat, circular blanks, the drawing ratio (blank diameter to cup diameter) can seldom exceed 2:2; higher ratios require redrawing in one or more stages. The article is a summary of a systematic investigation into redrawing by *(a)* the direct, and *(b)* reversed methods. With method *(a)* the external surface of the first-stage cup remains on the outside of the redrawn cup, whereas with *(b)* the cup is turned inside out so that the inside surface of the first-stage cup becomes the outer surface of the resulting shell.

The work was carried out on annealed steel of 0.08% carbon, soft and half-hard 99.0% aluminum, all 0.039 in. thick, and on annealed 70-30 brass in four thicknesses from 0.025 to 0.048 in. Provision of special subpresses enabled various die and punch combinations to be used, the five punch diameters varying from 2.666 to 3.1666 in. Radial clearance between punch and die wall was 0.060 in., and the blank holding force was 2300 lb. for steel and 1600 lb. for other metals. To obtain comparable results, certain standard conditions were adopted for preparing the first-stage 4-in. diameter cups from blanks of 6 to 8½ in. diameter.

Tests on redrawing steel and brass cups without intermediate annealing showed the second metal to have a considerably inferior redrawing capacity. For method *(b)* the punch load was consistently lower than for *(a)*, this being presumably due to the smaller amplitude of plastic bending in the latter. Since bending (or unbending) under tension results in thinning of the metal, the walls were somewhat thinner in the direct-redrawn cups. Fracture in redrawing took place, as a rule, at the "neck" formed in the region of the punch profile where the metal remained relatively soft after the first draw.

Interstage annealing of the first-stage brass cups for 30 min. at 500° C. (930° F.) enabled a reduction from 4 in. to 2.666 in. diameter to

*(Continued on p. 218)*

*Digest of "Cylindrical Shells — An Experimental Investigation Into Redrawing", by S. Y. Chung and H. W. Swift, *Iron and Steel*, Vol. 26, February 1953, p. 63-66.


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## Redrawing of Cylindrical Cups

*(Continued from p. 216)*

be obtained by process *(b)*, compared with a reduction from 4 to 2.79 in. for *(a)*. Without annealing, a reduction from 4 to 3.04 in. was possible with *(b)*, but attempts to produce 3.166-in. cups by unidirectional redrawing *(a)* were unsuccessful. Interstage normalizing of steel cups improved the redrawing ratio in *(b)* from 4 : 2.916 to 4 : 2.666 in., and a still higher ratio might have been attained if redrawing punches smaller than 2.666 in. were available.

It was found that the radial clearance in the first-stage drawing affected the behavior of the cup in subsequent redrawing, the redrawing load being maximum for 30% clearance and minimum for zero clearance. Moreover, when two cups — initially drawn with these two extreme clearances from 8½-in. blanks — were redrawn by method *(b)* from 4 to 3.041 in. diameter, the first cup broke whereas the other was drawn successfully. The obvious cause for this difference was the much thinner rim in the cup drawn with zero clearance, since the thickness of the rim is one of the factors governing the maximum redrawing load.

Comparison between the two redrawing methods showed that method *(a)* requires higher punch loads than *(b)*. Since *(a)* causes more thinning, the redrawing *stresses* differ even more than the loads. For both brass and steel the load difference mentioned above becomes smaller as the redrawing ratio increases. This is due to the drop of bending stress as a result of the larger radius of die profile provided by the greater redrawing ratio.

When cups obtained from 8-in. blanks were redrawn by method *(b)*, it was found that steel and half-hard aluminum drew successfully with the 2.916-in. punch but brass and soft aluminum failed. With the 2.791-in. punch all cups failed except those of half-hard aluminum. It seems, therefore, that materials of marked strain-hardening characteristic, like brass, are best for drawing from a flat blank, whereas those whose initial yield strengths are high in relation to their flow stresses under severe distortion, such as half-hard aluminum,

*(Continued on p. 220)*


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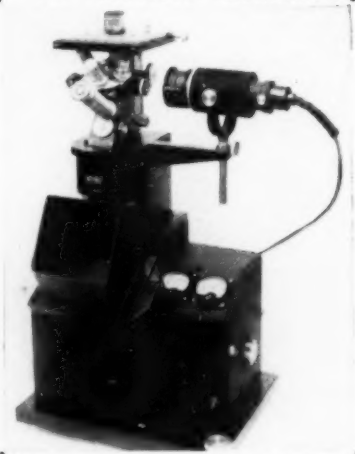

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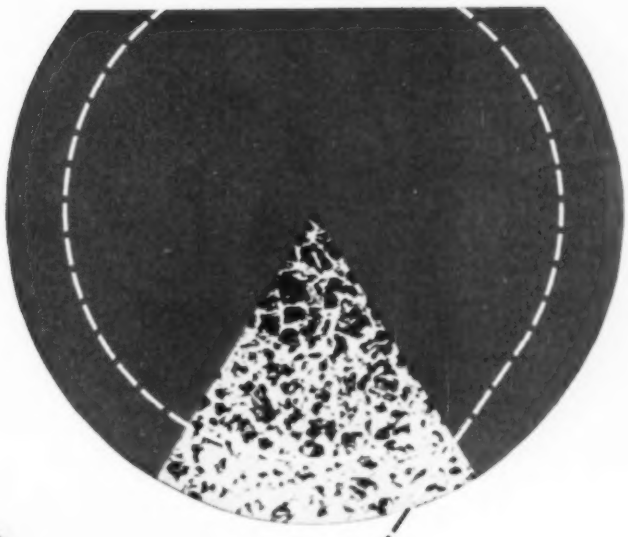
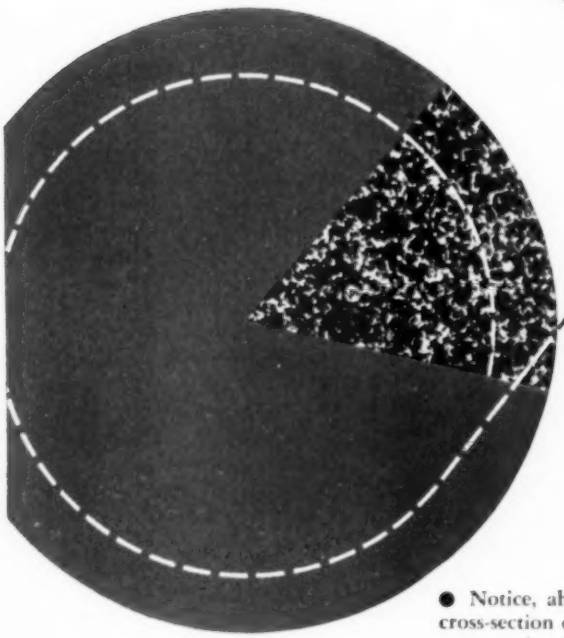


*The "decarb" (light-colored) area in the ordinary heat-treated bar at right must usually be removed before parts can be made from the stock.*



*Notice that this Republic carbon corrected alloy steel bar has had full carbon content restored to outer edges by carbon correction.*

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● Notice, above at the right, the "decarb" area in the outer edge of the cross-section of a cold drawn alloy steel bar as ordinarily heat treated. Then compare it with the cross-section below at the left. Notice how the carbon has been restored by carbon correction even to the extreme outer circumference.

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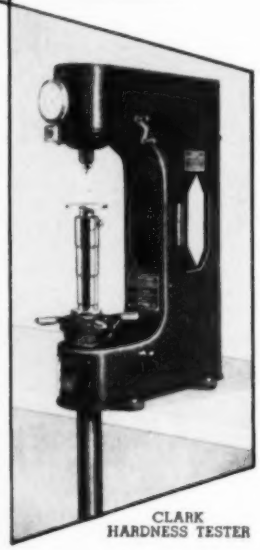

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## Redrawing of Cylindrical Cups

*(Continued from p. 218)*

are more suitable for redrawing.

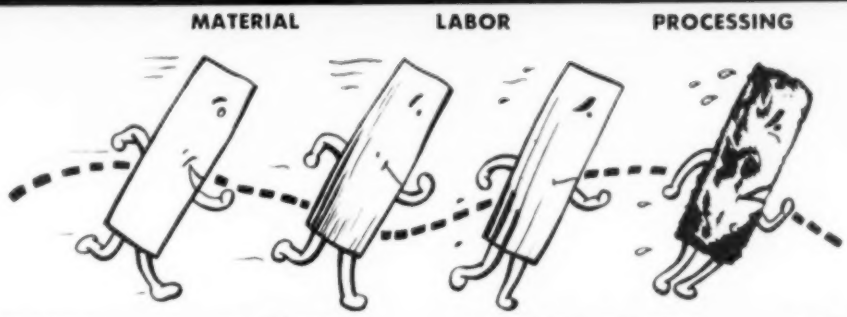
The effect of blank thickness on redrawing properties was explored on brass cups pressed from blanks 8 in. diameter and 0.048, 0.039, 0.032, and 0.025 in. thick. Redrawing after annealing was successful for all reductions and thicknesses by employing method *(b)*, but only the two thinnest cups could be redrawn by *(a)*. The failure of the thick-walled cups in direct redrawing was undoubtedly due to the higher drawing stress set up in the metal by the more severe flexure with a smaller ratio of the die-profile radius to the blank thickness. Also, the thinning (to which reference has already been made) is more pronounced with the thicker material when drawn by method *(a)*, this in turn acting so as to increase the actual drawing stress still further.

The authors conclude that the significant difference between the two redrawing methods lies in the number of bending operations and in the degree of severity of bending. When this severity is the same for both methods, the reverse method definitely gives better results. On the other hand, unlike the reverse method, the direct method can, within limits, be designed to provide a larger die-profile radius, and under favorable conditions may yield a better drawing capacity than the reverse method (a suitable tool design is suggested by the authors). To obtain the maximum combined drawing capacity over two stages, a first-stage blank of maximum size should be used, although the redrawing capacity by itself is greater with smaller initial blank diameters. Within the range covered by the experiments, there was no appreciable difference in redrawability as between hemispherical and flat-headed punches.

In view of the very considerable amount of experimental data contained in this work, and which appear to be of considerable practical interest, those directly interested are advised to consult the original paper when this is published in the 1952 *Proceedings* of the Institution of Mechanical Engineers.

N. H. Polakowski

OLD PROCESS

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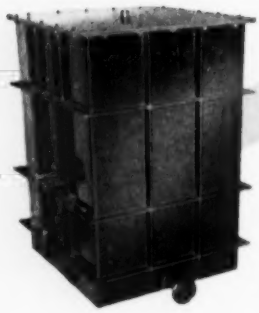

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ATLAS Ampcoflex **FABRICATIONS**


## Modified Rods for Welding Nodular Iron*

SUCCESSFUL welding of conventional gray cast iron has long been known to be dependent upon careful control of residual stresses in the weld area, because the flake graphite in the iron has little malleability and does not permit relief of such stresses by plastic deformation. This fact has suggested that the newer nodular irons might be welded more readily, since their graphite is in nodular or spheroidal form and can withstand some plastic deformation. Also, the nodular irons are lower in sulphur and phosphorus content.

To establish the validity of this hypothesis, extensive experiments were carried out on both electric arc and oxy-acetylene welding of nodular iron plates ½ in. thick, and pipe of 4 in. diameter and ½ in. wall thickness. Initially, three types of arc welding electrodes were tried: mild steel, alloy with about 60% Ni, and proprietary rods developed specifically for welding cast iron. Specimens included both magnesium and cerium-treated irons, in the pearlitic as-cast form, and in the ferritic fully annealed condition.

It was impossible to weld successfully with electric arc methods any type of nodular iron without preheating to at least 570° F. Failure occurred in the weld deposits as longitudinal and transverse cracks.

For gas welding, two types of filler rods were used in connection with a proprietary cast iron welding flux. The rods were a high-silicon cast iron type supplied for welding ordinary gray iron, and a cast iron rod containing nickel. Successful welds were laid down on the plate specimens, but preheating was required for the pipe to prevent crack formation. Gas welds gave fairly low physical test results, due to the formation of a flake-type graphite in the weld. Some hardening also occurred at the junction of the weld deposit with the nodular iron plate.

The magnesium and cerium-treated rods gave successful welds with any form of nodular iron plate or pipe specimen, as well as with ordinary flake-graphite iron specimens.

*Digest of "Ferrous Rod for Welding Nodular-Graphite Cast Iron", by R. V. Riley and J. Dodd, *Foundry Trade Journal*, Vol. 93, Nov. 13, 1952, p. 555-560.

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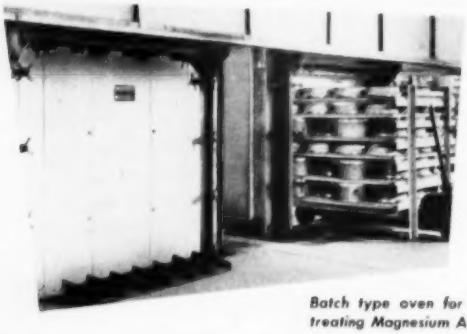

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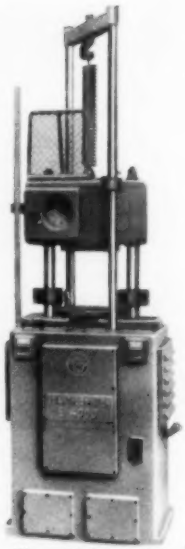

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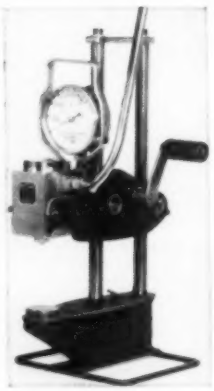

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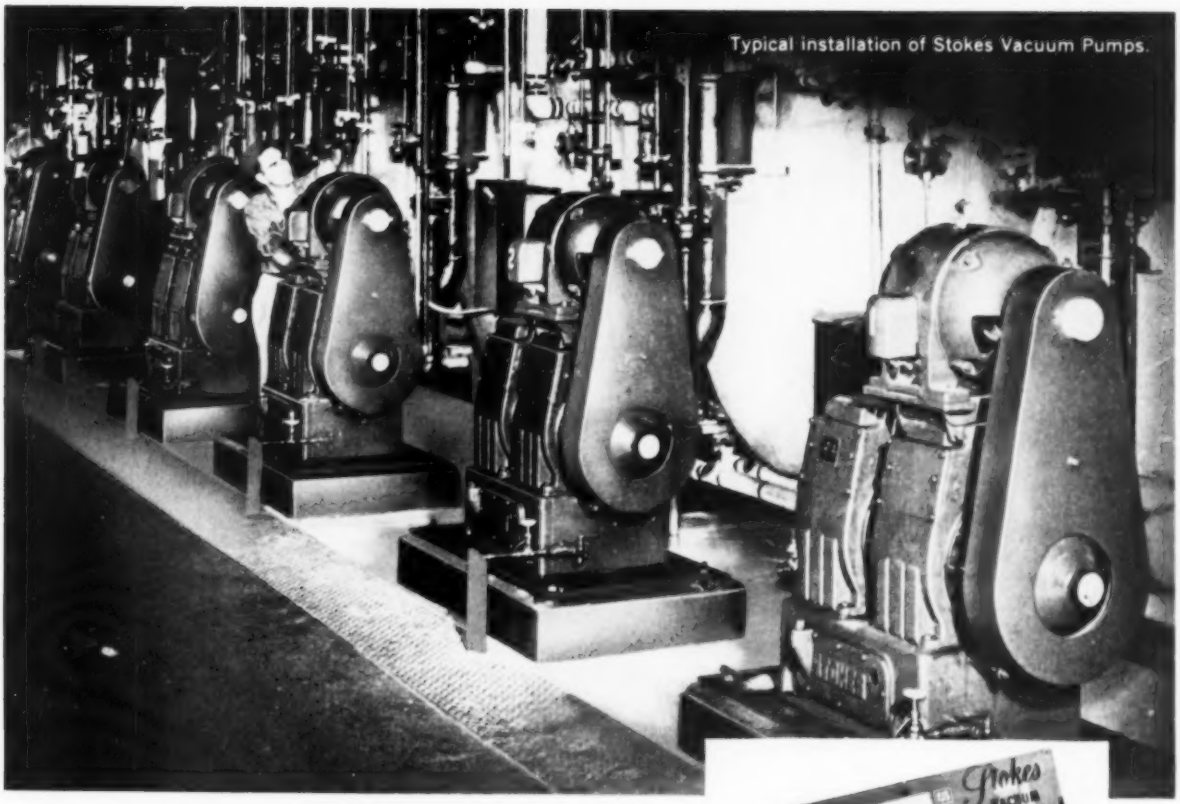

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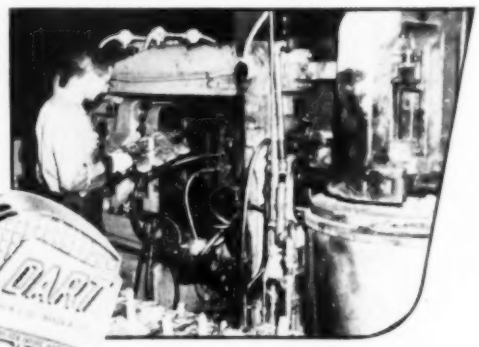

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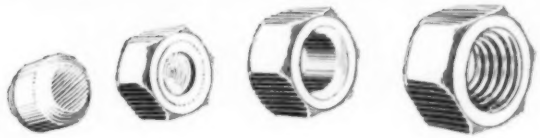

●Scrapless Nut Quality Wire is not an ordinary steel for common applications. It is a custom-built product designed to meet customers' specific requirements for cold heading, cold forging, cold punching, cold expanding and threading, in the production of a variety of nut shapes on continuous cold heading and cold forging machines.

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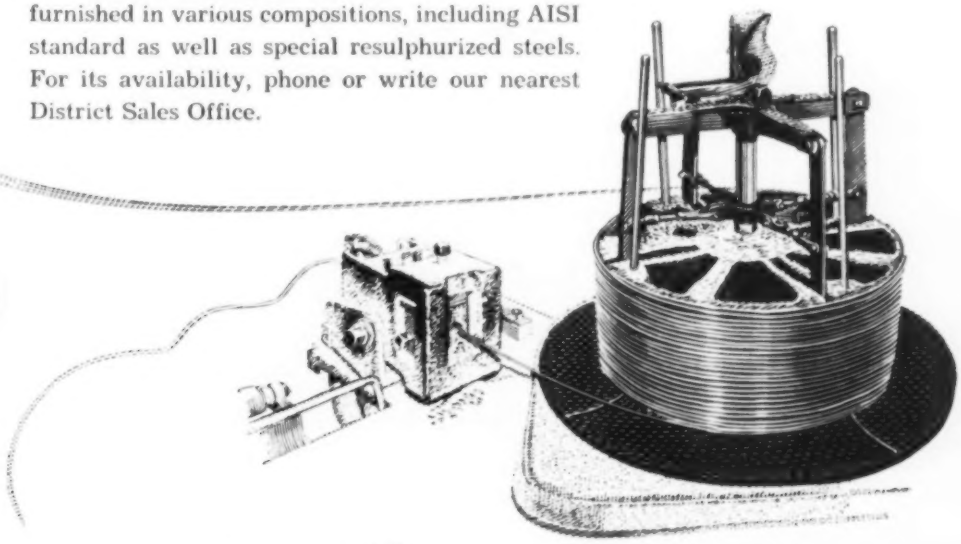
Youngstown's Scrapless Nut Quality Wire is furnished in various compositions, including AISI standard as well as special resulphurized steels. For its availability, phone or write our nearest District Sales Office.



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# Here's a CVC team that meets every *high vacuum* leak detection requirement

***Consolidated Engineering Leak Detector, Model 24-101A*** *(above) is a simplified mass spectrometer sensitive to minute traces of helium. It can be used with either the probe or envelope method. The self-contained unit includes mechanical and diffusion pump; and all necessary controls and instruments.*

***CVC Leak Detector, Model LD-01*** *(above right) uses a sensitive element containing a heated platinum anode and cold cathode with relatively low voltage between them. The circuit uses standard radio tubes, operates on 115-volt ac current.*

***For routine maintenance of your high vacuum system***—*CVC's* Model LD-01 Leak Detector is a compact, easily portable unit. It's simple to operate. You just connect the sensitive element to your vacuum system and pump a moderate vacuum. Then, direct a small jet of harmless Freon Gas at suspected spots and watch the meter. You get a direct indication of leak rate.

***For production work***—the Consolidated Engineering Leak Detector (Model 24-101A) will solve your problems. Whether it's a *large vacuum metallizer, vacuum furnace, refrigerator compressor drying system* or *TV-tube pumping system*, this versatile and extra sensitive unit will tell you when it's absolutely leak tight. Most specifications for hermetically sealed relays now require a leak tolerance detectable *only* with this type of unit.

Operation is simple—just play helium on the suspected area. An audio system tells the size of the leak by a low or high-pitched sound, or you can watch for it on a meter.

Either or both of these instruments will save you many hours of wearisome searching for vacuum leaks. For information on this or any other equipment, for the creation, measurement or use of *high vacuum*, write to ***Consolidated Vacuum Corporation, Rochester 3, New York*** (A subsidiary of Consolidated Engineering Corporation, Pasadena, Calif.) Sales offices: Menlo Park, Calif. • Chicago, Ill. Camden, N. J. • New York, N. Y.

formerly DPi Vacuum Equipment Dept.

## Consolidated Vacuum Corporation

**Rochester 3, N. Y.**

***high vacuum research and engineering***

# RESEARCH IS, AT TIMES, CONFUSING . . . .

OVER 300 years ago, Bacon said, in substance: "Whereas most of the great inventions that have benefited mankind have been stumbled upon by accident, surely, if we but search with *method* and with *order*, we will discover far more." He who would find a better way must first evaluate his own ignorance. He must seek and acquire the broadest possible *understanding* of preceding and contemporary work in all related arts, crafts and sciences which might lead and aid him toward enlightened understanding mandatory to progress.

Little is new or "original". Our heritage of human experience ascending up the geometrical progression of science, and accelerated by periodic joint efforts against our enemies, is beyond comprehension. An even greater wealth of thought and theory descends from men, who, through the ages, have envisioned ingenious devices centuries or generations before availability of materials and process to project them to function in the service of man.

Many patents, for example, were issued on furnace mechanisms, and on flying machines, a generation before the development of high temperature alloys—and of gasoline engines, essential to their function. Let him who thinks he is an Artisan, a Designer or a Foundryman visit our Museums. There, many messages from good minds and skilled hands await him. Centuries have winnowed the Wheat from the Chaff. Many "haystacks" of theory and stuff have rotted away and revealed a few "needles" of truth. For comparison, visit an "Antique" show. Note the "junk" that was the product of cramped minds or crude hands. It has not improved with age but is venerated for its "antiquity". Even that is often spurious.

Most paths of mankind follow the "water level route", or wind through the valleys and passes. Wherever the going is tough, they deviate from the *true course* to follow the "line of least resistance". Such paths do not attain altitudes of perspective. Few climb an Alp—fewer tunnel *through* one. As science and industry built better tools, Buck Fever ($) spread. Most "paths" of traffic and production were *widened*. Many remain to be *straightened*. Too many paths and "flow charts" still follow the zigs of departed "sacred cows" or the zags where Gramp outflanked the Indians to boost production a few wars behind.

Straightening of routes and process begins with *straight thinking*. It is conceived and accomplished by men *dissatisfied* with the Status Quo who refuse to remain Quiescent Under Obsolescence! They know that *life* demands *movement*, that *movement* is *change*, that change alone is *certain* and that change *forward* is *Progress*.

Such men are inspired by goals *beyond* the dollar. They have LOYALTY to the vision of work-well-done; MENTALITY to perceive *integrity and function* in *men*, *machines* and *metals*—VITALITY (and how they need it!) to fight entrenched resistance-to-change, and to strip Bull Dogs' Collars from the "Rabbits" whose *personal* fear of change renders them rampant against progress. Those who say "my product is good enough for me" are *correct!* Mediocrity finds its own level!


**HELP WANTED**

Undersigned is directing research and development and pilot production projects on advanced casting process and comprehensive engineering effort, in applying metallurgical design and stress evaluation to high integrity castings in all metals to replace forgings and fabrications in aircraft and ordnance. Have challenging opportunities for Metallurgists and Engineers. Men of *loyalty, vitality, mentality, stability*, and *judgment*. Men *above the herd* who perceive the potentials of advancing a vital sector of basic industry. Work in Boston, Illinois, California.

H. H. HARRIS, 405 W. First St., Boston

As our efforts in Research and Development proceed toward improvement of casting process, we strive to *understand, integrate* and *up-grade* many related arts, crafts and sciences. Many claims have been staked on advanced casting theory and process. Few have been conscientiously *worked*. Fewer have *produced*. "Nuggets" competently and laboriously panned-out in laboratories still await conversion through industrial process to negotiable "coin".

Many "Elephants" and fundamentals were, *and are*, variously reported, not by "four blind men"—but by *hundreds*. The coincidence of a "short-circuit-between-the-ears", with the urge to talk and write "technically" on casting process is the best documented fact in the "literature of the art".

It is becoming increasingly recognized that variations in as-cast structures are generally much more important in physical expectancies, particularly fatigue life of many cast metals and alloys, than considerable changes in chemistry. As-cast structures, specifically, "grain size" are, in general, a *direct function of the solidification rate of metal in the mold*. Basic factors are: (A) metal temperatures, and (B) heat transfer in, and from, the mold.

No insurmountable obstacles to understanding and improved control of such factors are envisioned. Much has, in fact, been accomplished. Yet, much academic-constafusion and pseudo-scientific apcray which has been published on this subject, and on colloidal theories of "plasticity", bonding of clays and mold materials, etc., etc., is as confusing and misleading to student and foundryman as if contrived to deceive.

Mr. R. W. Ruddle, Editor for the British Institute of Metals, presents a bibliography of the literature on "heat transfer in molds" which lists comparative data presented by seven leading "authorities". Comparison of data reveals about 700% variation, and is capped by comment to the effect that one employing such data might well be in grave error—a classic British understatement!

Our Hound may be looking at the prints of a club-footed bird or may have been "born cross-eyed", as has been suggested. Time alone will tell. Perhaps the greatest challenge in Research and Development is that it *is*, at times, confusing. Those who know-all-the-answers or who are habituated to playing a sure-thing, should best abstain from such effort.

The quest for truth is deeply satisfying. Once a few grains are isolated and established, they are harder to "sell" than 10 tons of "Baloney". The *appetite* for Baloney comes naturally. The *taste* for truth must be acquired, as any Politician or Scientist can testify.

—An editorial by the President of General Alloys Co., Boston, Mass. "Oldest and largest exclusive manufacturer of Heat and Corrosion Resistant Alloys."

H. H. Harris


THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

GA X-ITE GA COLLOYS GA X-ITE GA COLLOYS

*Acid Disc Inspection* backed by *Ultrasonic Testing* is just one of many Carpenter quality controls.

# IF YOU USE TOOL STEEL, THESE ARE FACTS YOU SHOULD KNOW

When you make or use a tool or die you invest a sizable sum of money. And there are steps you normally take to protect your investment. You make sure the design is right. You follow through with accurate toolmaking and correct heat treating. But there is *one* factor involved in the success of your die, over which you have only indirect control. That factor is the *soundness* of the die steel you start with. After all, if the steel itself isn't right, you needlessly risk your entire investment.

How can you be *sure* the die steel you use has what it takes to assure good tools? The answer lies in the painstaking controls regularly practiced by the steel manufacturer. Listed here are the four important tool steel controls pioneered by Carpenter to give steel users like yourself the protection you need. Before you place that next tool steel order, ask yourself, "Does our steel supplier guarantee these four quality controls in the die steel we use?" Then remember: You can be *sure* of them when you specify Carpenter Matched Tool and Die Steels. And you don't pay anything extra! THE CARPENTER STEEL COMPANY, 133 W. Bern St., Reading, Pa.

**4 Tool and Die Steel Developments *Pioneered by Carpenter* Help Carpenter Customers Cut Costs, Improve Die Performance**

***Since 1929:***

**HOT ACID DISC INSPECTION** has been standard practice at Carpenter. To Carpenter customers it provides full assurance that Matched Tool and Die Steels are internally sound, shipment after shipment.

***Since 1930:***

**The TOUGH TIMBRE TEST** has assured Carpenter users a wider safe hardening range, greater dependability in performance.

***Since 1933:***

**The TORSION IMPACT TEST** has provided Carpenter Matched Tool and Die Steel users with more complete heat treating information that leads to better tools and dies.

***Since 1940:***

**The CONE TEST**, used to check and control hardenability of Carpenter water-hardening Matched Tool and Die Steels, has made sure that sections of the same size have uniform hardness penetration in lot after lot.

**Carpenter** STEEL

**Matched Tool and Die Steels**

Export Department: The Carpenter Steel Co., Port Washington, N.Y.—"CARSTEELCO"

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# NEW Streamlined AB SPEED PRESS

The most advanced design in press equipment for speed, convenience, and economy in the production of Bakelite and Transparent Molded Specimen Mounts ever presented to the metallurgist.

A revolutionary feature introduced in this new press is preheated Premolds. The preheat compartment reduces the curing time of thermo-setting molds to one-third of the time usually required. It enables the operator to produce perfect Bakelite Mounts in 2½ to 3½ minutes. All necessary indicators and controls including pressure gauge, pyrometer, thermostats, timer and pilot lights are provided. No experience is required to produce perfect mounts. Automatic ram retraction saves time and effort.

The hinged press head is made with a semi-automatic lock and a hand wheel screw to close the mold securely. Heating blocks are arranged with a magnetic closure to snugly envelop the mold assembly. The interchange of thermostatically controlled heating units of 600 watt capacity is facilitated by convenient supports. Cooling blocks are located in a practical position in front of the press cabinet.

This new speed press is the result of long exacting experiment, with every effort devoted to designing the finest modern specimen press we are able to engineer.

No. 1330 AB Speed Press, complete for 1" mountings ..... $420.00

No. 1330-2 AB Speed Press, complete for 1¼" mountings ..... $440.00

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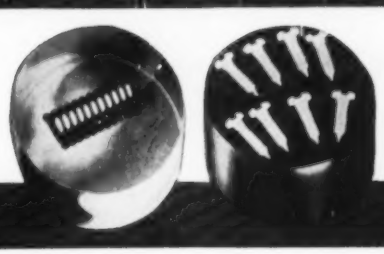
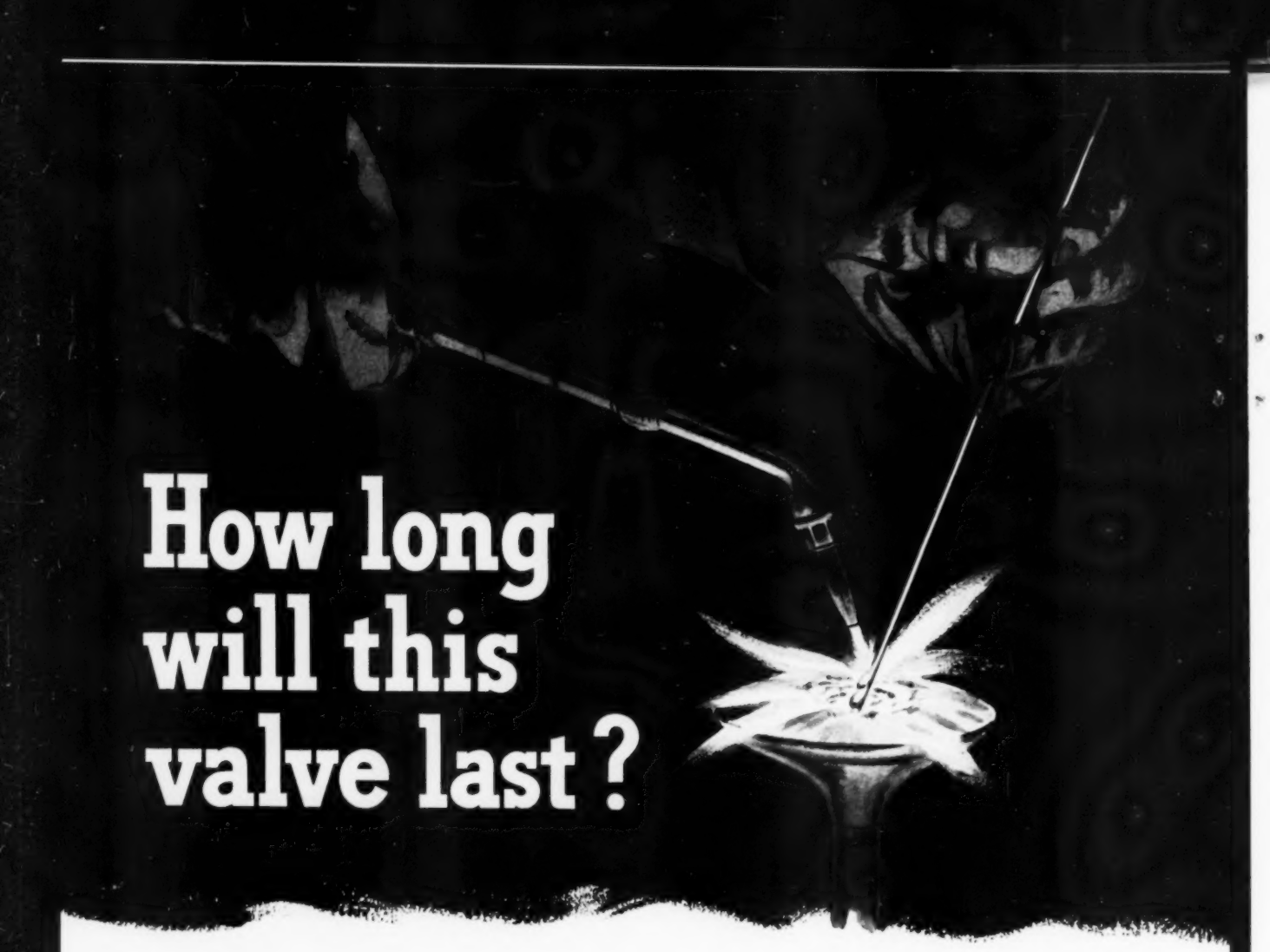
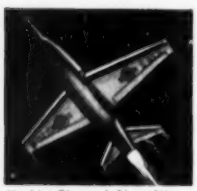


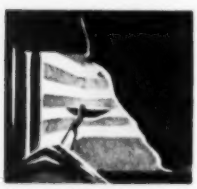
METALLURGICAL APPARATUS



# How long will this valve last?



Hoskins Chromel-Alumel thermocouple alloys accurately register exhaust temperatures of jet aircraft engines.



Heating elements made of Hoskins Chromel give long life service in industrial electric furnaces, home appliances.

Hot stuff for hot jobs! Hoskins Alloy 502 is widely used by industry for many heat resistant mechanical applications.

You're looking in on a life-saving operation . . . one that's being performed on an engine valve. Not an ordinary valve for an ordinary engine. But a valve destined for long, hard service in an aircraft, tank, or heavy-duty truck engine. A valve that must be made to stand up under extremely severe operating conditions . . . high temperatures, for long periods of time, plus the destructive corrosive action of hot exhaust gases.

And what's responsible for long valve life under such gruelling conditions? Nothing less than Hoskins Alloy 717 . . . a closely controlled nickel-chromium composition developed especially for just such tough and vital service. It's highly resistant to heat . . . immune to the corrosive atmospheres created by combustion of high octane fuels. What's more, it's readily applied by fusion to form a non-porous protective facing over the basic valve forging.

But 717 is only one of several specialized nickel-chromium alloys developed and produced by Hoskins. Among the others: Alloy 502 . . . known throughout industry for its dependability on a wide range of heat resistant mechanical applications. The Chromel-Alumel thermocouple alloys . . . unconditionally guaranteed to register true temperature–E.M.F. values within specified close limits. Spark plug electrode alloys which have become universally accepted standards of quality and durability. And, of course, there's Hoskins CHROMEL . . . the *original* nickel-chromium resistance alloy used as heating elements and cold resistors in countless different products.

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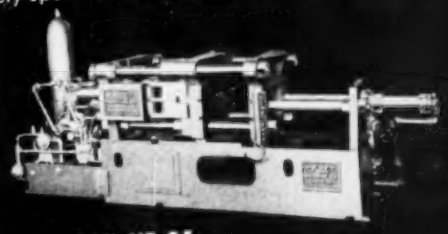
Here are many of the important Names among the companies that produce precision die castings to order. Whether during peace or war, these die casting jobbers are known for maintaining the highest standards of quality. Use of KUX Die Casting Equipment helps make this possible.

Continual study and improvement for over 30 years is responsible for the many exclusive engineering design superiorities that have made KUX machines the finest in their field. That's why you can be sure of maximum efficiency when you rely upon KUX Die Casting Machines.



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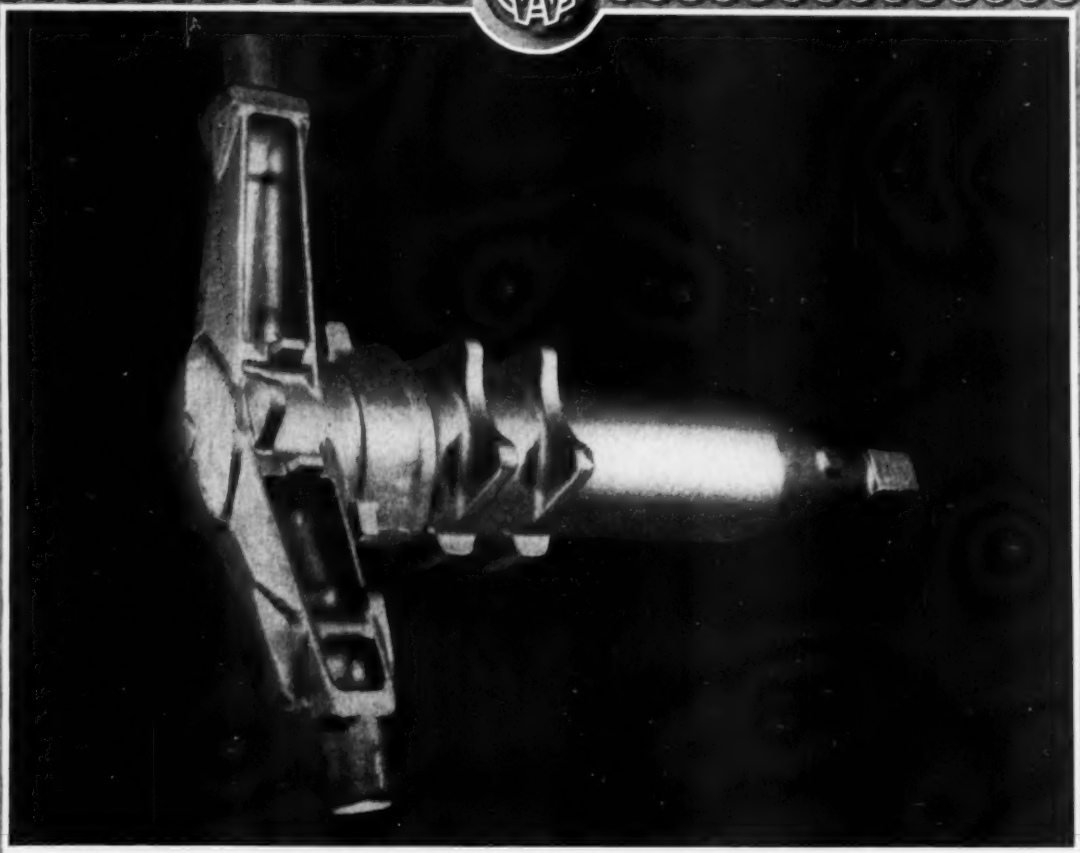
**SELECTED BY FIRST NAMES IN INDUSTRY**



***Forgings*** for the aircraft industry today demand the utmost in engineering and production techniques and in scientific laboratory control. This massive complicated landing gear component, weighing over 400 pounds, is typical of Wyman-Gordon's forging contribution to the ever-growing progress in aircraft design. In crankshafts for the automotive industry and in all types of aircraft forgings, steel and light alloy, Wyman-Gordon has pioneered in the development of forging "know-how"—there is no substitute for Wyman-Gordon experience.

***Standard of the Industry for More Than Sixty Years***

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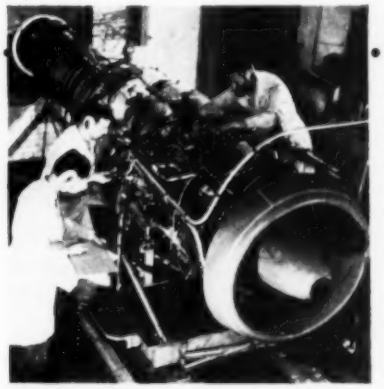
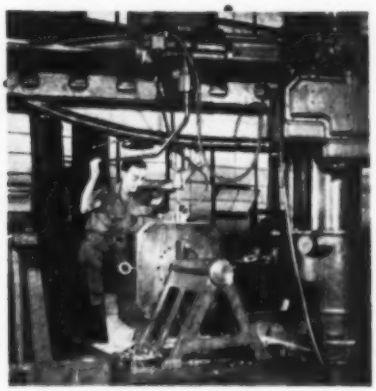
# MAKE IT ALLOY

*Versatile, dependable Chromium Steels are doing more different jobs today than ever before.*

**Constructional Alloy Steels**—For greater strength and hardness in crankshafts, springs, transmission gears, countershaft pins, sway eliminator bars, through-hardened bearings and other critical parts, much of the alloy steel used by makers of automotive and farm equipment now contains chromium.



**Stainless Steels**—Every well-known type of stainless—both straight chromium grades and chromium-nickel grades—owes its resistance to heat and corrosion primarily to chromium.



**Tool Steels**—Whether for cutting, hot and cold forming, or die casting, whether the end product is a hand chisel or a forging die, nearly every present-day type of tool steel gets much of its strength and hardness from chromium.

*The finest alloy steels are made with Vancoram ferro alloys.*

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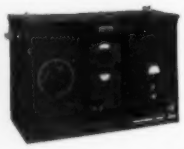

Control Panel regulates current input.

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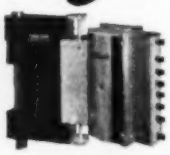

Compensating Furnace Bracket

In high temperature tensile, creep and stress-rupture tests of alloys, maintenance of uniform temperature in heating chamber is of top importance. Research engineers write us this is one of their favorite features in Marshall Furnaces.

In Marshall Furnaces, excellent heat balance is assured at all times by the carefully spaced coils, and the zone-by-zone temperature adjustment. Use of Marshall Control Panels, too, assures a still further refinement in minimizing temperature fluctuations.

Marshall Brackets for furnaces are made in stationary and compensating types.

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ARE able to supply you promptly

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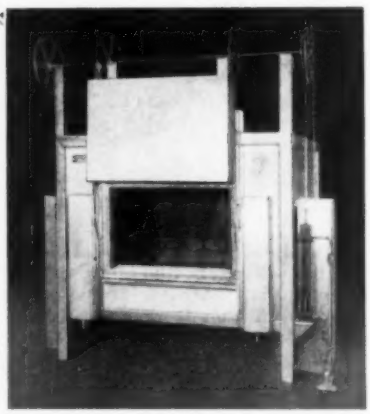
# PERECO *Electric* FURNACES

**MODEL TF-24**

**Operating temperature 2400° F.**

***For* Heat Treating and Porcelain Enameling**



Where you need a roomy work chamber (36" w. x 48" d. x 24" h.) this new model TF-24 — typical of the line of Pereco Electric Kilns — offers "top" performance from every standpoint. Globar elements deliver closely controlled temperatures over the full range up to 2400° F. Powered for extremely rapid "recovery" time. Counterbalanced door is foot controlled. Ideal for wide range of work — including heat-treating and porcelain enameling. Handles 350 lbs. of metal per hour. Atmosphere-tight, all-welded steel construction.

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***For your specialized need Pereco offers standard or special units from 450° F. to 5000° F.***

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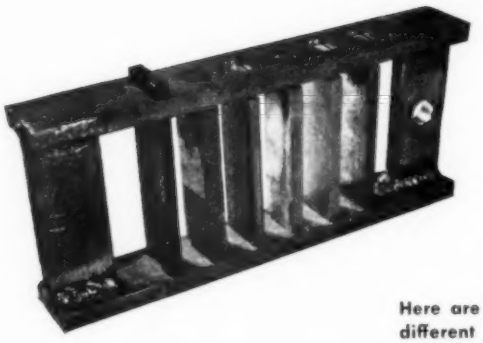
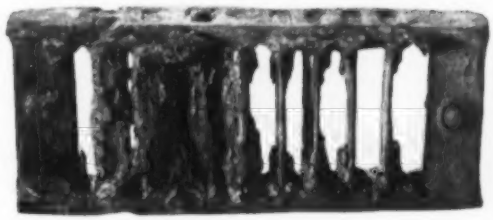


Here are before and after photos of test racks of different alloys. The "after" photo (below) shows how the alloys react with exposure to high-temperature corrosion in tests. It's through tests like this that Inco's High-Temperature Corrosion Engineers are able to determine the material to recommend for special operating conditions.



# What's Your High-Temperature Problem?

## Inco High-Temperature Corrosion Engineers want to help you solve it.

Anyone working with the higher operating temperatures has undoubtedly run into the common problem of equipment failure.

Engineers have found that corrosion quickly spells death to many metals when the temperatures mount.

That's why Inco established a High-Temperature Engineering Service to search out and determine what materials would stand up best under unusual corrosive conditions at high temperatures.

Laboratory tests by Inco Engineers have solved many high - temperature metal problems. Constant research is adding to this fund of information.

Inco Engineers in the field are learning of conditions that cause unsatisfactory performance and how best to remedy them. Data on a variety of industrial applications has been collected.

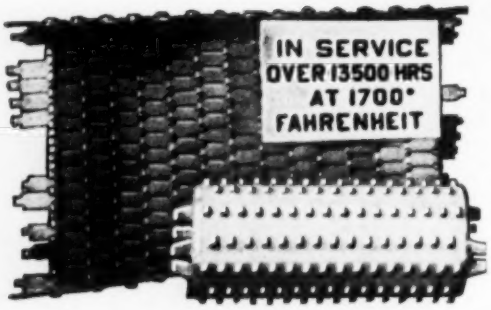
If you have a high temperature problem, Inco's High - Temperature Engineering Service may have the answer you are looking for – if not, you can be sure they will attempt to get it as soon as possible.

Send today for your copy of the High-Temperature Work Sheet. It is a specially developed simplified form to aid you in setting down your problem so that our engineers can go to work on it.

EMBLEM OF SERVICE INCO

**THE INTERNATIONAL NICKEL COMPANY, INC.**
67 Wall Street, New York 5, N. Y.

# HOT SPOTS require the use of *Pyrasteel* PARTS




PYRASTEEL Sprocket and section of Belt Conveyor . . . a typical high-temperature application with a record of exceptionally long service.

**PYRASTEEL Drag Chains** are widely used in the cement and allied industries. Even when immersed in molten clinker, they do not warp, break or oxidize.

When you need extra durability in high temperature applications, specify PYRASTEEL Parts. This chrome-nickel alloy provides maximum resistance to heat and corrosion at temperatures up to 2000° F., and it also resists corrosive gases and most concentrated or dilute commercial acids.

PYRASTEEL adds to the service life of refinery fittings, furnace parts, conveyor screws, and food and chemical processing equipment.

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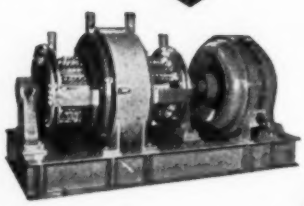

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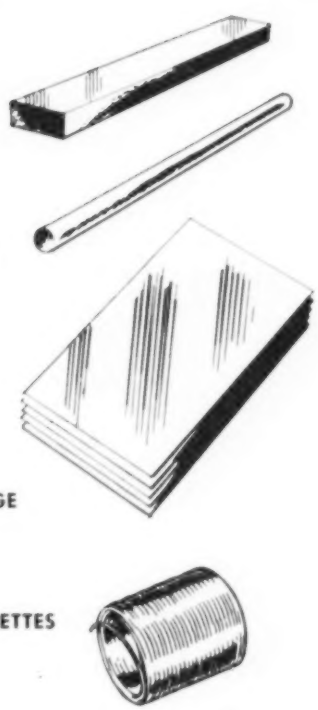

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## *Easier buffing of copper deposits*

Another improvement achieved in the Unichrome Pyrophosphate Process maintains its wide current density range and permits fast, smooth plating over long periods of time. The plate is so smooth that little or no buffing is required. When it is, the copper "flows" under the buff wheel, minimizing the time and work. As a pyrophosphate solution, Unichrome Copper poses no cyanide waste disposal problems. More data in Bulletin CU-2.

## Plastisol coating outlasts metal 4 to 1 in corrosive application

Here's a case showing the extraordinary protection that can be given to metals.

Bleach reduction chambers of a noted chemical producer were coated with a Unichrome Plastisol Compound. This user reported that the coating gave 4 times longer service than even special alloy metals before requiring maintenance! The exceptional chemical resistance displayed by these vinyl coatings is fortified by the thickness they develop–up to 3/16". Tough and elastic, they bake to stable form at 350° F. The Technical Service Department of United Chromium can be consulted on the suitability of these compounds for any specific application.

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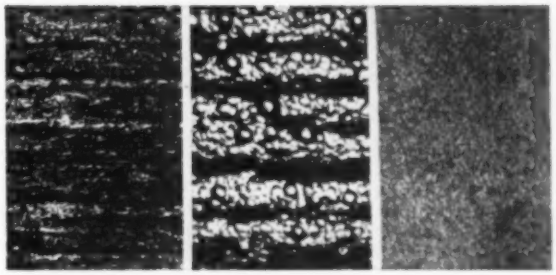
## New economies found through unusual chromium deposits produced by Unichrome SRHS Bath

A NEW ENGLAND manufacturer, plating dies and plugs in the Unichrome SRHS Chromium Bath instead of the ordinary bath, found that tool life was being substantially increased. At the same time, plating time had been cut in half.

This case highlights the essential improvement that has been made since the advent of SRHS Chromium Solutions – that it is now possible to plate at *higher* speed and still get far *smoother* deposits than heretofore.

These advantages are well known in the field of decorative plating. But the unusual nature of the deposits and the speed become all the more striking when "hard" or relatively thick plating is done.



*Untreated steel* | *Plated in ordinary bath* | *Plated in SRHS Bath*

### PHOTOMICROGRAPHIC EVIDENCE

The photomicrographs above show the reason why the Unichrome SRHS Solution produces a smooth plate. With unusual "leveling action," this bath smoothed over the minor surface irregularities – while producing a 40% thicker plate than the ordinary chromium bath, in the same time, and under the same conditions.

Such a deposit saves grinding and polishing. This saving cuts required deposit-thickness which still further reduces plating time.

### ANOTHER REASON FOR SPEED

Unichrome SRHS Chromium Baths have wider bright plate range. As a result, full advantage can be taken of higher operating curent density for fast deposition of metal without burning on projections. Deposits also show little or no evidence of "treeing," even at high speeds.

### MINIMUM EFFECT ON STEEL

Chromium plating increases steel's resistance to corrosion and wear. But it is known also to reduce its fatigue limit. Research shows, however, that high strength steel plated in SRHS Chromium suffers the smallest loss of fatigue strength. This is clearly shown by these tabulated results from an independent university laboratory on heat-treated test specimens plated with .001" of chromium.

| *Chromium Plating Solution* | *Fatigue Strength psi* | *% Loss Over Unplated* |
|---|---|---|
| Unplated | 81,500 | – |
| Ordinary | 60,500 | 25.7 |
| SRHS CR-100 | 75,200 | 7.7 |
| SRHS CR-110 | 75,300 | 7.6 |

Hard chromium plating in the SRHS Bath, therefore, can enable designers to specify lighter parts or smaller cross sections while maintaining the usual safety factors. Platers are finding more and more of their industrial customers *specifying* SRHS Chromium Plating for this reason.

• • • •

While it's still chromium, you can see there's a distinct difference when it's deposited from a Unichrome SRHS Chromium Bath. In addition, the bath offers operating advantages: It can regulate itself, minimize control problems, and maintain peak plating balance. With higher cathode efficiency, it also cuts power requirements and increases capacity without extra equipment.

Write or phone for more data. Or better still, ask a United Chromium finishing engineer to give you all the facts.

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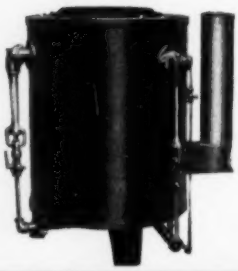

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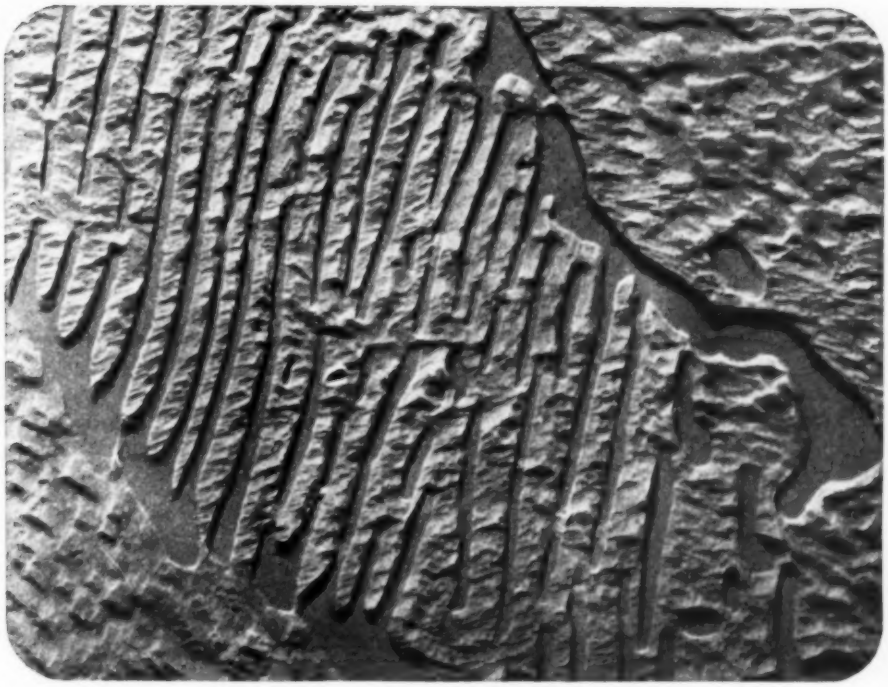
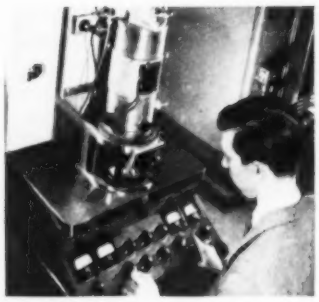


# How the RCA *electron microscope* helps U. S. Steel forecast product quality



**Robert M. Fisher,** of United States Steel, viewing the image of a shadow-cast collodion replica of a polished and etched surface of steel—in the RCA Electron Microscope.

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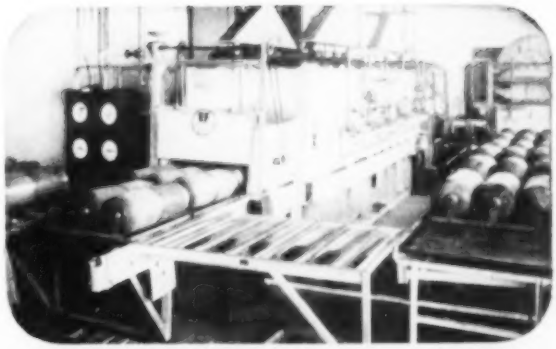

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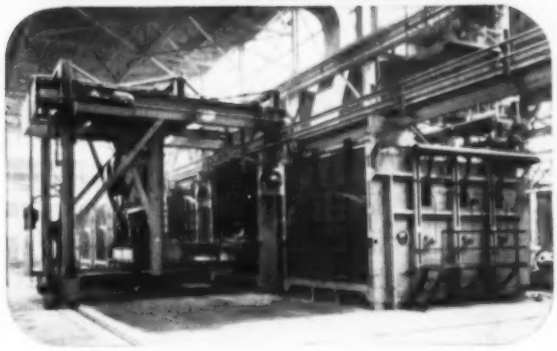

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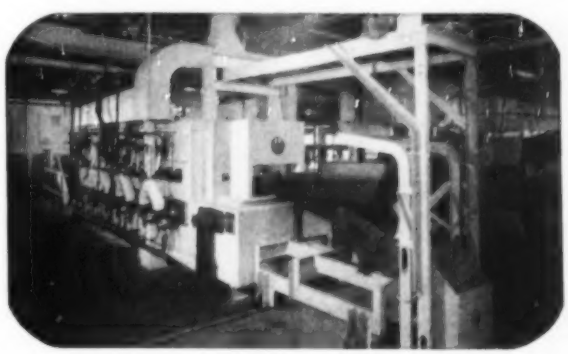
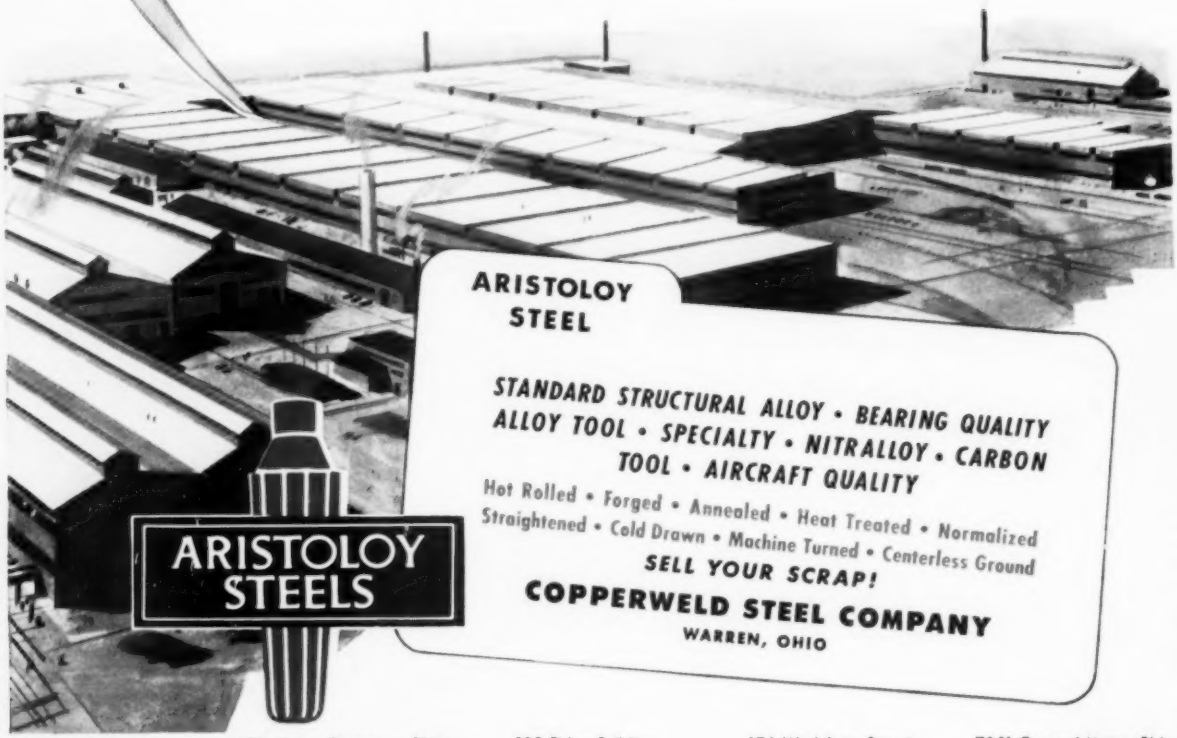


Bolts, springs and other products are scale-free heat treated in EF continuous chain belt conveyor furnaces similar to the one at right. 11 sizes—to handle from 125 to 2000 lbs. or more per hour. Hundreds are in operation.

# More Steel Coming Up!

Copperweld has been growing since 1941. Recently more floor space has been added—blooming and bar rolling capacity increased—new furnaces added. Last year our output increased 30 per cent over what had been a good year.

Despite this however, we are still unable to serve our friends to the full extent of their requirements. Accordingly we have stepped up our expansion program. The results are not yet apparent in improved service on Aristoloy Steels—but we will soon be able to better meet your needs.




**ARISTOLOY STEEL**

*STANDARD STRUCTURAL ALLOY • BEARING QUALITY*
*ALLOY TOOL • SPECIALTY • NITRALLOY • CARBON TOOL • AIRCRAFT QUALITY*

*Hot Rolled • Forged • Annealed • Heat Treated • Normalized*
*Straightened • Cold Drawn • Machine Turned • Centerless Ground*

*SELL YOUR SCRAP!*

**COPPERWELD STEEL COMPANY**
WARREN, OHIO

117 Liberty Street, New York, New York
1578 Union Commerce Bldg., Cleveland, Ohio
528 Fisher Building, Detroit, Michigan
176 W. Adams Street, Chicago, Illinois
7251 General Motors Bldg., Detroit, Michigan
3104 Smith Tower, Seattle, Washington
P. O. Box 1633, Tulsa, Oklahoma
325 W. 17th Street, Los Angeles 15, Calif.
Monadnock Building, San Francisco 5, Calif.
1140 Lockwood Drive, Houston 20, Texas
803 Loew Building, Syracuse, New York